36442

National Library of Canada | Bibliothèque nationale du Canada

CANADIAN THESES ON MICROFICHE | THÈSES CANADIENNES SUR MICROFICHE

NAME OF AUTHOR/*NOM DE L'AUTEUR* AJIT KUMAR MOHANTY

TITLE OF THESIS/*TITRE DE LA THÈSE* PERCEPTION OF AMBIGUOUS SENTENCES: EFFECTS OF BIAS AND AMBIGUITY TYPE

UNIVERSITY/*UNIVERSITÉ* THE UNIVERSITY OF ALBERTA

DEGREE FOR WHICH THESIS WAS PRESENTED/ *GRADE POUR LEQUEL CETTE THÈSE FUT PRÉSENTÉE* Ph.D.

YEAR THIS DEGREE CONFERRED/*ANNÉE D'OBTENTION DE CE GRADE* 1978

NAME OF SUPERVISOR/*NOM DU DIRECTEUR DE THÈSE* DR. W.H.O. SCHMIDT

Permission is hereby granted to the NATIONAL LIBRARY OF CANADA to microfilm this thesis and to lend or sell copies of the film.

The author reserves other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without the author's written permission.

L'autorisation est, par la présente, accordée à la BIBLIOTHÈQUE NATIONALE DU CANADA de microfilmer cette thèse et de prêter ou de vendre des exemplaires du film.

L'auteur se réserve les autres droits de publication; ni la thèse ni de longs extraits de celle-ci ne doivent être imprimés ou autrement reproduits sans l'autorisation écrite de l'auteur.

DATED/*DATÉ* November 23, 1977 SIGNED/*SIGNÉ* [signature]

PERMANENT ADDRESS/*RÉSIDENCE FIXÉ* SADAR THANA ROAD
PURI, ORISSA, INDIA

NL-91 (3-74)

National Library of Canada

Cataloguing Branch
Canadian Theses Division

Ottawa, Canada
K1A 0N4

Bibliothèque nationale du Canada

Direction du catalogage
Division des thèses canadiennes

NOTICE

The quality of this microfiche is heavily dependent upon the quality of the original thesis submitted for microfilming. Every effort has been made to ensure the highest quality of reproduction possible.

If pages are missing, contact the university which granted the degree.

Some pages may have indistinct print especially if the original pages were typed with a poor typewriter ribbon or if the university sent us a poor photocopy.

Previously copyrighted materials (journal articles, published tests, etc.) are not filmed.

Reproduction in full or in part of this film is governed by the Canadian Copyright Act, R.S.C. 1970, c. C-30. Please read the authorization forms which accompany this thesis.

THIS DISSERTATION
HAS BEEN MICROFILMED
EXACTLY AS RECEIVED

AVIS

La qualité de cette microfiche dépend grandement de la qualité de la thèse soumise au microfilmage. Nous avons tout fait pour assurer une qualité supérieure de reproduction.

S'il manque des pages, veuillez communiquer avec l'université qui a conféré le grade.

La qualité d'impression de certaines pages peut laisser à désirer, surtout si les pages originales ont été dactylographiées à l'aide d'un ruban usé ou si l'université nous a fait parvenir une photocopie de mauvaise qualité.

Les documents qui font déjà l'objet d'un droit d'auteur (articles de revue, examens publiés, etc.) ne sont pas microfilmés.

La reproduction, même partielle, de ce microfilm est soumise à la Loi canadienne sur le droit d'auteur, SRC 1970, c. C-30. Veuillez prendre connaissance des formules d'autorisation qui accompagnent cette thèse.

LA THÈSE A ÉTÉ
MICROFILMÉE TELLE QUE
NOUS L'AVONS REÇUE

THE UNIVERSITY OF ALBERTA

PERCEPTION OF AMBIGUOUS SENTENCES: EFFECTS OF BIAS AND AMBIGUITY TYPE

by

AJIT KUMAR MOHANTY

(C)

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF EDUCATIONAL PSYCHOLOGY

EDMONTON, ALBERTA

SPRING, 1978

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled PERCEPTION OF AMBIGUOUS SENTENCES: EFFECTS OF BIAS AND AMBIGUITY TYPE submitted by AJIT KUMAR MOHANTY in partial fulfilment of the requirements for the degree of DOCTOR OF PHILOSOPHY.

W H Ohmidt
.....
Supervisor

M D Jackson
.....

.....

R J Mulcahy
.....

Allison
.....
External Examiner

Date November 21, 1977

To

my parents

and

to the memory of

my grandfather and father-in-law

ABSTRACT

A review of the studies supporting the unitary perception and the exhaustive computation hypotheses of ambiguous sentence perception suggested two important factors in developing an appropriate model -- i) bias, set and context effects, and ii) type of ambiguous sentences. Conventional experimental tasks to index sentence complexity were also found unsuitable for comparing ambiguous and unambiguous sentences. Measures of heart rate (HR) change were proposed instead. Following the works of Lacey (1959, 1967; Lacey & Lacey, 1970) it was suggested that if ambiguous sentences are processed exhaustively the degree of HR acceleration during their processing and subsequent deceleration should be greater compared to unambiguous sentences.

For Experiment 1, six high- and six low-bias ambiguous sentences and their respective pair of controls were selected from a previous study (Mohanty, Note 1). High- and low-bias sentences were those for which more than 80% and 50-70% of the paraphrase responses, respectively, indicated the same meaning. The sentences, divided into three randomised lists each with clusters of two high-, two low-bias ambiguous and eight unambiguous sentences, were presented visually to 30 male undergraduates (10 subjects per list). Sentences were exposed for five seconds each followed by intervals of 15 seconds, one second tone

(warning signal), five seconds interval, and four second probe-words. Subjects were instructed to indicate by a button-pressing response if the probe words related to the meaning of the sentences.

Percentage of HR acceleration following the sentences were analysed in a Groups x Ambiguity x Bias x Sentence Cluster repeated measures Latin square design. Significant Ambiguity x Bias and Ambiguity effects were obtained. Further, ambiguity effect was significant in the low-bias condition but not in the high-bias condition. Percentage of HR deceleration data showed significant effect of ambiguity for both the bias conditions. Analysis of RT to probe-words of different types suggested that exhaustive computation of low-bias ambiguous sentences is followed by a perceptual suppression process leading finally to acceptance of one meaning.

In Experiment 2, with the bias of ambiguous sentences controlled at 50-70% (low-bias) level, effects of lexical, surface- and deep-structure ambiguity on perceptual complexity of sentences were compared in a similar design and using the same measures as Experiment 1. Eighteen ambiguous sentences (six from each type) and their corresponding pair of controls were divided into three lists with two sentences from each of the ambiguity types and 12 unambiguous control sentences and were presented to 30 male undergraduate subjects in three groups. Analysis of the

percentage of HR acceleration scores showed significant Ambiguity x Type and Ambiguity effects. Acceleration due to ambiguity was significantly greater for the deep structure condition compared to the surface structure and the lexical conditions. Ambiguity effect was significant for HR deceleration. Analysis of RT to probe words showed significant Ambiguity x Type interaction.

The results were interpreted as supporting the hypothesised dual process model -- unitary perception for high bias and exhaustive computation for the low bias ambiguous sentences and as showing that the perception of ambiguous sentences is primarily a cognitive phenomenon. While deep structure type of ambiguous sentences were shown to be more complex, it was suggested that the nature of such perceptual mechanism is not yet fully understood.

ACKNOWLEDGMENT

This work was supported by a Killam Doctoral Fellowship. I am thankful to the Killam Scholarship Committee for the award.

My sincere thanks to Dr. W.H.O. Schmidt who supervised this work with care, understanding and patience. I am grateful to Dr. J.P. Das whose penetrating wisdom and insight have been extremely valuable to me in going through this experience. I thank Dr. M. Jenkinson for her scholarly comments on various aspects of this work. Dr. R.F. Mulcahy has been very helpful throughout this research. I am particularly thankful to him for teaching me the handling of the Polygraph. Thanks to Dr. J. Osborne for his help and encouragement.

I am thankful to Dr. T. Maguire and Dr. S. Hunka for their help in statistical analyses of the data. Thanks to Mr. L.M. Samantaraya of the Department of Civil Engineering for helping me revise the computer program for Heart Rate scoring and analysis.

I am also thankful to Drs. W.J.M. Baker, G.D. Prideaux, and B.L. Derwing from the Department of Linguistics for their interest in this work and encouragement.

Thanks to Mrs. Emma Collins for her understanding and administrative support which contributed a great deal to the

progress of this work. I am also thankful to Mrs. Heather Bishop of the Data Entry Services for her able management of the preparation and production of this manuscript.

My wife Bina actively participated in the work by her help in conducting the experiments, scoring the data and in contributing to all other aspects of this work.

I am grateful to all my friends and professors in the Department who have shown an active interest in this work. Special thanks to Drs. R. MacArthur, J. Bishop, L. Stewin and C. Hallschmid.

Finally, thanks to Dr. D.R. Olson for consenting to be the external examiner for this work. His ideas have influenced this work from its outset and his comments have been very encouraging.

TABLE OF CONTENTS

CHAPTER	PAGE
I. INTRODUCTION AND REVIEW	1
Models for Perception of Ambiguous Sentences	4
Unitary Perception Hypothesis: a non-interaction process	4
Exhaustive Computation Hypotheses	8
Perceptual suppression process	12
Perceptual closure process	16
An Overview of Some Issues in Ambiguity	23
Effects of Bias, Context, and Set	25
Types of Ambiguity and their relative effects	29
Nature of the Tasks and Psycholinguistic Processes	34
Heart Rate as a measure of Information Processing	36
II. EXPERIMENT 1	44
Rationale and Hypotheses	44
Method	53
Stimulus Sentences and Probe Words	53
Selection of Sentences - A pilot study	53
Selection of Probe Words	57
Design of the experiment	58
Subjects	63
Apparatus	63
Procedure	65
Results and Discussion	67
Heart Rate	67

CHAPTER PAGE

HR acceleration 70

HR deceleration 73

Reaction Time 75

Discussion 86

Congruence between HR and RT 89

III. EXPERIMENT 2 93

Rationale and Hypotheses 93

Method 96

Stimulus Sentences and Probe Words 96

Design of the Experiment 97

Subjects 98

Apparatus 98

Procedure 98

Results and Discussion 99

HR acceleration 99

HR deceleration 104

Reaction Time 106

Discussion 108

IV. GENERAL DISCUSSION AND CONCLUSION 111

Perception of Ambiguous Sentences and the Language User's Knowledge of the World 111

Perception of Ambiguous Sentences and the Types of Ambiguity 116

Interaction among the Meanings following Exhaustive Computation 119

Implications 119

Conclusions 121

REFERENCE NOTES 122

REFERENCES 123

APPENDICES 130

Appendix A: Sentence Interpretation and Ambiguity Rating Questionnaire 130

Appendix B: Stimulus Sentences and Probe Words Used in the Study 139
Experiment 1 140
Experiment 2 142

Appendix C: A comparative Summary of the Models of Ambiguous Sentence Perception 145

CHAPTER I

INTRODUCTION AND REVIEW

> 'For names are finite and so is the sum-total of formulae, while things are infinite in number. Inevitably, then, the same formula and a single name have a number of meanings.'
> Aristotle, De sophisticis elenchis.

Ambiguity, or the phenomenon of multiple meaning, is an unavoidable property of natural language. However, it has often been discussed as a pathology of language -- as a phenomenon that is responsible, at least in part, for lack of clarity or equivocation in language. Aristotle discussed ambiguity in several of his writings to expose the fallacy involved in certain reasonings and the deceit of concealing one proposition within another. Since Aristotle, a number of philosophers and linguists, Quintilian, Vaugelas, Bally, and Jespersen, to name only a few, have looked upon the phenomenon of ambiguity "as a shortcoming of language users, as a deficiency of the system of natural language or both (see Kooij, 1971, for a discussion)." On the other hand, there are those like Empson (1930) who have considered ambiguity in language as necessary. Empson (1930) quoted from the preface of Oxford Poetry, 1927 to describe the two opposing forces in literature and poetry: "an asceticism tending to kill language by stripping words of all associations and a hedonism tending to kill language by dissipating their sense under multiplicity of associations (p. 234)." Empson considered his seven types of ambiguity as

'beautiful' when they maintain the unity of the ideas that must be expressed and understood the way the author wanted them to be. Empson concluded,

> An ambiguity, then, is not satisfying in itself, nor is it, considered as a device on its own, a thing to be attempted; it must in each case arise from, and be justified by, the peculiar requirements of the situation. On the other hand, it is a thing which the more interesting and valuable situations are more likely to justify (p.235).

Whereas the negative view looks upon ambiguity as an evil in the communication system, in the positive view of Empson it is, under certain circumstances, necessary and justified. The former is, obviously, in sympathy with the recipient of a message -- the reader or the hearer -- because ambiguity is thought to be deceitful and misleading. The positive view, on the other hand, is in sympathy with the speaker or the writer because ambiguity is seen as a tool that he must occasionally use to preserve the unity of the language system and to express multiple ideas in a single proposition. However, there is nothing inherently beautiful or deceitful in a potentially ambiguous utterance; it is beautiful when, as Empson has argued, it effectively communicates the speaker's ideas to the hearer and it is deceitful when it fails to do so. In other words, in certain cases, in the use of puns for example, it is desirable that the reader or hearer perceive the ambiguity in a sentence to appreciate its meaning. Such perception, however, depends upon the nature of the mechanism that we normally use to

comprehend what we read or hear at least as much as it does on the formal nature of the language input. In fact, ambiguity exists only in the interaction between the two. The present work deals with certain aspects of this process of understanding the meaning or meanings of sentences that can be potentially ambiguous.

Three major models of perception of ambiguous sentences have been proposed. According to the Unitary Perception model (Garrett, 1970; Lashley, 1951) we process only one possible meaning of an ambiguous sentence; the other meaning is ignored unless justified by a subsequent context. Two other models, however, have suggested exhaustive computation of all meanings leading to the acceptance of one (Foss, 1970; Foss & Jenkins, 1973; Lackner & Garrette, 1972; MacKay, 1966; Shanon, 1974). One of these, the Perceptual Suppression model (MacKay, 1970; Olson & MacKay, 1974) hypothesises a simultaneous and subthreshold activation of all meanings competing to suppress each other in an interactive process. Finally, the Perceptual Closure model (Bever, Garrett, & Hurtig, 1973) suggests an exhaustive process of perceptual mapping from the surface to the underlying structure within the boundary of each (ambiguous) clause at the end of which there is a perceptual closure involving acceptance of one meaning before the next clause, if any, is processed. This model postulates differences between lexical, surface structure, and deep structure types of ambiguous sentences in terms of processing time and

difficulty. A discussion of these models and a review of the evidence in support of each suggests that there is no clear support for any single model and that a number of factors must be considered in dealing with the major issues in the area (see Mohanty, 1976, Note 1). They are: i) bias, linguistic and non-linguistic context, perceptual set, and subjective salience of a meaning etc., ii) type of ambiguous sentences (e.g. lexical, surface-, and deep structural), and iii) nature of experimental task (e.g. reaction time, picture verification time, completion time, etc.).

MODELS FOR PERCEPTION OF AMBIGUOUS SENTENCES

a) Unitary Perception Hypothesis: A non-interaction process

There has been some claim that hearers of an ambiguous sentence process one possible meaning at a time; the other meaning is ignored completely unless a subsequent context of the sentence seems to justify it. It is as if he is led along the 'garden path' and must go back to the starting point when he discovers the interpretative error (Garrett, 1970). Lashley (1951) wrote about 'priming' of a particular meaning by a subthreshold activation of a whole system of associations which leads to an anticipation of a particular structure in the speaker as well as the hearer. Lashley's idea is a neurophysiological translation of the Wurzburg School's concept of 'determining tendency' or Bewusstseinslage which postulated existence of a mental set

or a plan before the recognition of the temporal ordering of a sentence. Lashley was trying to argue that a linear probabilistic model (Markov process) is inadequate and that one has to assume an integrative structure which causes a selective access of one meaning of an ambiguous unit. After priming his audience with the phrase 'rapid writing' Lashley read the sentence,

> Rapid | riting | with his uninjured hand saved from loss the contents of the capsized canoe

and pointed out that the associations which give meaning to 'righting' are not activated until the hearer hears 'capsized canoe'. Comprehension of the meaning of a sentence is usually governed, according to this model, by a congruence between the 'determining set' and the meaning derived from semantic and syntactic relations of the words. When ambiguity is noticed the two meanings are not processed simultaneously in an interactive manner; they are accessed and evaluated one after the other. In other words, computation of one meaning is independent of computation of the other.

The unitary perception hypothesis has one advantage, namely that of relying on the economy of our sentence comprehension mechanism. Since part of what we hear is ambiguous in some way or other perception of one meaning at a time must be an effective way of handling the ambiguous input. The semantic context of such input serves to effectively bias the perceptual process toward the related

meaning. Even when prior context of an ambiguous sentence does not have any obvious or strong biasing effect this hypothesis would claim that we normally take any meaning available first and go along with it until it is disconfirmed. In any case, perception of an ambiguous sentence poses no special problem as such. However, it is quite likely, as Thorne (1966) has argued, a hearer of an ambiguous sentence sometimes keeps both the interpretations with a certain degree of belief in each and abandons one on subsequent contact with a disambiguating context.

Experimental support for the unitary perception hypothesis. Some experiments have shown that, in processing the meaning of sentences, people take as much time for ambiguous sentences as they do for unambiguous ones. Foss, Bever, and Silver (1968) asked their subjects to verify whether or not pictures shown at the end of a sentence represented its meaning. Verification time for ambiguous sentences was longer than that for unambiguous ones only when the pictures depicted 'unexpected' meaning of the ambiguous sentences. Cairns (1970) replicated the results of Foss et al. (1968) using disambiguating sentences instead of pictures.

Results of these studies were interpreted as supporting the garden path phenomenon. However, they can also be interpreted as showing that although people compute both meanings of ambiguous sentences they compare the meanings

serially with the more probable meaning compared first.

Studies by Carey, Mehler, and Bever (1970a, 1970b) used a setting technique to deliberately introduce bias in favor of one meaning of the ambiguous sentences. Bias was defined as the probability that one of the meanings is perceived rather than the other. Ambiguous sentences like They are visiting sailors were preceded either by five progressive sentences (e.g. They are unearthing diamonds) or by five adjectival sentences (e.g. They are incoming signals). When the syntactic set was strong enough so that it elicited a set-compatible response and also the subjects were unaware of the other meaning, the processing of ambiguous sentences required no more time than the processing of unambiguous ones. This study, of course, does not unconditionally support the unitary perception hypothesis. The results show, at best, that when there is a strong biasing context, perceptual process can be directed toward one meaning ignoring the other. As will be shown later, this study as well as others demonstrates the necessity of considering the effect of context or bias as a significant variable in developing a model of perception of ambiguous sentences. The term 'bias' is used here very broadly to include all the factors that determine the relative strength of the meanings of an ambiguous sentence. In other words, bias can be thought of as a combination of factors determining the probability with which hearers of an ambiguous sentence accept one meaning over the other. Support for the unitary

perception hypothesis seems to be limited, at least, by such effect of bias.

b) Exhaustive Computation Hypothesis

All the meanings of an ambiguous sentence, according to this hypothesis, are covertly considered by the hearer before acceptance of one. Since both the meanings have to be considered processing of ambiguous sentences is hypothesised to be more difficult and longer. This model, it seems, draws its logical support from the analysis-by-synthesis model of speech perception and production proposed by Katz and Postal (1964). They suggested that a hearer analyses a string of linguistic input by synthesising a number of self-generated probable strings and analysis of the input is made by matching the internal strings with the input. Since a system which generates, at random, infinite number of strings for matching would be highly uneconomical, Katz and Postal also postulated some heuristic devices for cutting down the number of strings to be generated at any time. Further, this device seems to take cues from phonetic patterns and lexical associations to generate only plausible and limited number of strings. In case of ambiguous sentences, this means that the synthesising mechanism generates internal representations which are related to all the meanings and which interact with each other until the process of analysis is complete. Perception of ambiguous sentences is, thus, rendered more complicated involving interaction among the

meanings and also the choice of one of these.

The exhaustive computation hypothesis does not say anything about the process of interaction and decision making which leads to perception of one meaning. Obviously, parameters of such processes have to be incorporated into any such model of ambiguous sentence processing.

Experimental support for the exhaustive computation hypothesis: Some studies have shown that it takes longer to process sentences when they are ambiguous because accessing more than one meaning requires more time. MacKay (1966) had his subjects complete ambiguous and unambiguous sentence fragments and found that completion time for ambiguous fragments was longer than that for unambiguous controls even when the subjects were unaware of any ambiguity in sentences. He concluded that "ambiguity interferes with the appreciation of a single meaning of ambiguous sentences (p. 434)."

Foss (1970) used a phoneme-monitoring task which requires the subjects to press a button whenever a target phoneme occurs in aurally presented sentences. He found that reaction time was longer when the sentences were ambiguous. Using the same task, Foss and Jenkins (1973) also found that even when a prior disambiguating context was provided reaction time was longer to target phonemes in ambiguous words. Prior semantic context did not significantly change the difference between the reaction time for ambiguous and

unambiguous words. The authors suggested that all the meanings of ambiguous items are accessed and, then, stored in a working memory before any selection can be made. The extra meaning complicates the perceptual process, hence the longer reaction time for ambiguous words. However, some subsequent studies, using the same paradigm, have shown that when the biasing context is strong the effect of ambiguity on reaction time is eliminated (see Schvaneveldt, Meyer, & Becker, 1976).

In another experiment, Lackner and Garrett (1972) presented ambiguous sentences to the ear which the subjects were instructed to attend and disambiguating sentences (providing a biasing context) to the other ear. Subjects' paraphrases of ambiguous sentences were significantly influenced by the contextual information, although they could not give any information regarding the disambiguating sentences. The results were interpreted as showing that all of the meanings of ambiguous sentences are nonselectively accessed; the effect and relevance of biasing sentence depends on availability of these meanings. However, it is possible, as Schvaneveldt et al. (1976) pointed out, that the contextual information may have been processed prior to the ambiguous sentence, thus biasing its meaning.

In a study by Conrad (1974) the semantic context of ambiguous sentences did not influence what meanings were processed. She concluded that both the meanings of the

ambiguous lexical items in the sentence were accessed regardless of the context. However, in this study, since the subjects were given the same ambiguous word in different contexts, it is possible that they processed meanings related to all these contexts even if they normally do not do so.

Thus, the support for the exhaustive computation hypothesis is not conclusive. Again, the strength of the context seems to be important in determining if all the meanings are accessed and in what order. It is possible, as will be discussed later, that under certain conditions all the meanings of ambiguous sentences are nonselectively accessed whereas only one is processed under certain others. Further, the exhaustive computation hypothesis and the supporting studies, as discussed so far, do not say anything about the process of interaction between the meanings of ambiguous sentences. Assuming that people, at least covertly, consider all the meanings the question still remains how and when, if at all, do they decide which meaning to accept. Do they fluctuate from one meaning to the other like the figure-ground fluctuation in visual perception of reversible figures such as Necker Cube? Or do they make a choice, more or less immediately, from among all the possible meanings? There are two variants of the exhaustive computation hypothesis which differ on this question as well as on a few others. Each of these versions of the exhaustive computation hypothesis will now be

discussed in turn.

Perceptual Suppression Process: Suggested by MacKay (1970), the perceptual suppression model postulates initial activation of all the meanings of ambiguous sentences leading to an interactive subliminal process. "The basic assumption of the theory is that in order to perceive one meaning of an ambiguous sentence the other meaning must be suppressed and time to suppress a meaning varies with the salience of that meaning in the context of a sentence (MacKay, 1970, p. 86)." The model, thus, takes into account the relative salience or bias of the meanings and also the effects of context on the perception of ambiguous sentences. Bias of any meaning of an ambiguous sentence is defined as the probability of that meaning being perceived. Suppression of a meaning becomes increasingly difficult as its bias increases. A hearer, therefore, should take longer to process an ambiguous sentence or to perceive one of its meanings when the relative biases of both the meanings are equal. Once the meanings with certain salience are covertly activated interaction between them goes on with the help of cues from the linguistic and non-linguistic context until one of the meanings is boosted to the threshold and perceived. This process, called contextual integration by MacKay, takes place in two phases: preactivation phase and activation phase. During the preactivation phase the ambiguous input partially activates two simultaneous sets of interacting analysers the relative strengths of which are

determined by the bias of the meanings and the context within which the sentence appears. The interaction between the two sets of semantic analysers is mutually inhibitory so that activation of one follows suppression of the other. At the end of such interaction incomplete and ad hoc analysis of the sentence, with both its meanings activated, is fed into the integrative level for the next phase of analysis i.e., the activation phase. During this phase hypotheses regarding the two meanings are tested on the basis of information received from the analyser level. The hypothesis testing may proceed in a series of TOTE units to find out if particular features of the ambiguous input fit the characteristics of the context. For example, an ambiguous phrase like 'walking sticks' may have two sets of distinctive features; the term 'walking' could be a modifying adjectival term or it could be a verb. The second grammatical feature renders the meaning of the phrase as 'a stick that is walking' and the meaning is immediately found to be contextually incongruous and, therefore, dropped. The person then goes on to test other features like semantic markers and distinguishers. The strength of an analyser is increased as a result of confirmation of a test until, finally, it is boosted to the threshold and the meaning is perceived. Once a meaning is consciously perceived the other meaning may be released from inhibition and it may also be perceived. Thus, according to this model, perception of the meaning of an ambiguous sentence need not be an all-or-none

function; both the meanings may be perceived in turn and the perceiver may view them with tentative probabilities.

On the basis of his model MacKay (1970) predicted that time taken to perceive the ambiguity of a sentence will not be affected by whether the meaning seen first is more or less likely, i.e. by the bias or probability of the meaning first noticed, because one meaning has to be suppressed before the other meaning is perceived. Bias of the meanings was determined in a pilot study by computing the percentage of subjects who reported seeing each of these meanings first. MacKay, then, used a setting technique to favor one reading of the ambiguous sentences. After presenting four sentences of one structure (e.g. She wondered how often philosophers think.) he presented an ambiguous sentence (e.g. Mary wondered how little Sam drove cars.) The subjects were asked to verbalise, as soon as possible, the meanings of each of the sentences. Time to perceive both the meanings of ambiguous sentences was not affected by which reading of the ambiguous sentences was induced by the set. The setting technique was also used for a sentence completion task. Completion time was longer for the ambiguous sentence fragments than for the unambiguous ones. Completion time was also longer for the subjects giving a set-unlikely completion response than for those giving a set-likely response. It appears, the subjects who saw unlikely meaning took longer because they had to suppress the likely meaning.

In another study, Olson and MacKay (1974, Expt. I) gave a completion task to subjects with the bias of the meanings of each ambiguous sentence fragment predetermined. Subjects indicated, at the end of the experiment, which meaning they had perceived first and whether they perceived the ambiguity. Completion time for unnoticed ambiguous fragments was longer than for unambiguous controls. In the 40-50% bias range completion time for ambiguous sentences was longer than for their unambiguous counterparts. Percentage of noticed ambiguity was highest at the intermediate bias level and most of the incorrect completions also occurred at this level. In a second experiment Olson and MacKay (1974) used a verification task. Again, verification time at the 50% bias level was longer for ambiguous sentences.

The perceptual suppression process also incorporates the concept of 'plan' or 'determining tendency'. The notion of plan is central to the postulated TOTE model for testing rival hypotheses regarding the meaning of a sentence in the integrative system. A plan is "any hierarchical process in the organism that can control the order in which a sequence of operations is to be performed (Miller, Galanter, & Pribam, 1960, p. 16)." The plan may, thus, determine the order in which a person tests the competing hypotheses and, so, the meaning to be perceived first. It is possible that when the 'determining tendency' is quite strong in favor of one meaning the other meaning may be suppressed without much difficulty and the perceptual process may resemble that of

an unambiguous sentence. In such a case, any experimental task given during the processing of ambiguous sentences may not show any effect of ambiguity and the results may be interpreted as supporting the unitary perception model.

Perceptual closure process: Reviewing the studies on perception of ambiguous sentences, Garrett (1970) initially suggested that the two hypotheses (viz., the unitary perception and the exhaustive computation) are not mutually exclusive but reflect various stages in processing. Experiments showing the effect of ambiguity (i.e., supporting exhaustive computation hypothesis), he argued, used tasks initiated during the processing of the sentences whereas experiments showing no such effect used tasks after the processing had been completed. Bever, Garrett, and Hurtig (1973) developed a more elaborate perceptual closure model based on this earlier formulation by Garrett (1970). The model, first of all, accepts the distinction between the lexical and syntactic types of ambiguous sentences. Lexical ambiguity is due to the presence of words or sequence of words which may have two or more meanings. For instance, Take the right turn is lexically ambiguous because the word 'right' has, at least, two meanings viz., 'correct' and 'direction'. A sentence is syntactically ambiguous if the structural relations among the lexical items can be organised in more than one way. Further, the structural ambiguity may be either at the 'surface structure' level or at the underlying 'deep structure' level. Surface structure

ambiguity involves at least two possible groupings of the words. In the sentence They fed her dog biscuits, 'dog' can be grouped with either 'her' or 'biscuits'. The underlying structure of a sentence, on the other hand, may be ambiguous when at least two different logical relations among the words or the phrases are possible. Essentially, it involves different subject-object-verb relationships between the words or phrases of the main clause of the sentence. For example, the sentence They are the ones to help is ambiguous at the underlying structure level because "they" might stand in the role of the subject or the object in relation to 'help'. As such, the sentence might mean either they are the ones who need help or they are the ones who can help.

Turning back to the perceptual closure model, Bever et al. (1973) suggested that in the normal speech perception process the lexical sequences in the surface structure are projected into an underlying structure relationship. A hearer is able to discern the logical subject-verb-object relationships utilising the cues from the surface construction of a sentence. The linear relationships between the noun phrases and the verb phrases may vary from one surface structure to another as in the case of active-passive constructions but the deep structure remains the same because of what has been postulated as some kind of projection mechanism and internal labeling process. The relative complexity of the mechanism is partly determined by non-availability of cues in the surface structure to signal

any particular underlying structure relationship and by the number of potential underlying structures that a surface structure can enter into. One of the causes of complexity of sentences with multiple embedded clauses is lack of explicit clause markers like 'who', 'when' etc. (Fordor & Garrett, 1967; Hakes & Cairns, 1970).

When a sentence has a number of possible underlying clauses, each of them must be processed individually to avoid any overloading of the working memory capacity. Therefore, the model assumes that the clause boundary forms the primary perceptual unit in processing a sentence. As soon as the processing of one clause unit is over the linear surface form is dropped from the working memory which is made available for processing the next clause, if any. The clause which is already processed is possibly recorded into an abstract form and stored in the short-term memory. This principle of perceptual closure at the clause boundary has some experimental support particularly from the click-migration studies. In dichotic presentation of clicks and sentences, the clicks occurring within the clause are known to be perceptually relocated as occurring at points corresponding to the boundary between two underlying clauses[1] (e.g. Bever, 1970, 1971; Bever, Lackner, & Kirk,

---

[1] It must be pointed out here that click-migration studies have also been variously criticized for confounding effects of memory error and response bias (Reber & Anderson, 1970; Chapin, Smith, & Abrahamson, 1972) and for insensitiveness of the technique (Johnson-Laird, 1974).

1969). Similarly, the point of switching from one ear to the other is more accurately located if it occurs at the clause boundaries than if it occurs within a clause (Wingfield & Klein, 1970).

If ambiguous sentence perception is only a special case of the normal speech perception mechanism it can be assumed that during the analysis of a single ambiguous clause all possible meanings and structural alternatives are processed; perceptual closure, then, occurs at the end of such processing when one underlying structure is finally assigned. Any task initiated before such perceptual closure should be, as Garrett (1970) had pointed out, more complex because of the added computational load in case of ambiguity. In other words, such task performance should be more difficult or slower or both in the ambiguity condition compared to the unambiguous control condition. On the other hand, if the task demands a response which is initiated after the perceptual closure of the ambiguous clause it should not, any more, differentiate between the ambiguous and the unambiguous sentences.

In order to test the perceptual suppression model Bever et al. (1973, Expt. I) presented the subjects with ambiguous and unambiguous sentences and asked them to think up a next sentence in a hypothetical story. The subjects were also instructed to think of the response only after they had understood the sentence. Sentence ambiguity did not increase

the reaction time of the subjects. Bever et al. (1973) concluded, "....ambiguity does not complicate processing once a stimulus sentence is finished. That is, when a subject is encouraged to complete the interpretation of a sentence before thinking up a response, there is no interference from the 'unselected' meaning (p. 280)." In the second experiment Bever et al. (1973, Expt. II) found that, with a sentence completion task, subjects took longer to think up a response for ambiguous fragments than for unambiguous control fragments when all the fragments were incomplete clauses. When fragments were complete clauses completion time was shorter for ambiguous ones although the difference was not significant. Bever et al. (1973) also reanalysed part of MacKay's (1966) sentence completion data separating the incomplete clause fragments from the complete ones. The difference between the response latencies for the ambiguous and the unambiguous fragments was greater in case of the incomplete clauses. The results were interpreted in terms of greater processing load in case of incomplete ambiguous clauses, that is, prior to the perceptual closure. However, one can argue that in the incomplete clause condition the completion task is more difficult than the complete clause condition because the subjects have to provide more structural information in the former condition. An earlier study by Mistler-Lachman (1972) also contradicts the results of experiment I of Bever et al. (1973). In her experiment subjects took longer to think up an appropriate

sentence following a visually presented sentence when such sentence was ambiguous.

The perceptual closure model, thus, has not obtained a clear support from the available research. Further, any model of ambiguous sentence perception must provide for the possibility that both meanings may be tentatively accepted or, at least, must specify the conditions of interaction under which one of the meanings is finally perceived. A distinction must also be made between the types of pre-closure task given in different experiments on sentence ambiguity. In some cases, like the phoneme monitoring task, the required response is not directly related to or dependent upon the comprehension process. In others, like the sentence completion task, the response must depend upon the comprehension of the sentence fragments. Results of such experiments are, therefore, subject to different interpretations in terms of relationship between the task requirement and comprehension. Such interpretation would still support the exhaustive computation hypothesis but not necessarily its 'perceptual closure' version. Even if one assumes that subjects' knowledge of response requirements prior to perceptual closure would somehow interfere with both the sentence perception process and the response elicitation, this formulation would have difficulty in accommodating the results of Carey et al. (1970a, 1970b). In their experiments they found that the picture verification time was not longer for the ambiguous sentences compared to

the normal control sentences when the subjects did not notice the ambiguity. The perceptual closure model would assume that the verification response is initiated after the process of perception of the sentence is over. However, in these experiments, subjects had continuous visual access to the picture during the auditory presentation of the sentence; in fact, the sentences were presented 5 seconds after the pictures. Obviously, it is reasonable to assume that the response was already initiated when the subjects were processing the sentence.

The perceptual closure and the perceptual suppression models differ basically on two issues. One, according to the closure model both the meanings are computed but at the clause boundary only one meaning is accepted until disconfirmed by subsequent context. In other words, this model is an exhaustive computation model only up to a point; once the clause boundary is reached perception of the meaning resembles the unitary perception model. In fact, Clark and Clark (1977) have called this model a 'mixed theory' for this reason. The perceptual suppression model, on the other hand, is an exhaustive computation model all along, hypothesising fluctuation between the two meanings as long as the listener continues to attend to the ambiguous sentence. The second distinction between the two models is in terms of the parameters of ambiguous sentence processing. The perceptual suppression model accepts bias or strength of the meanings as an important determinant of the nature of

interaction between the meanings. The closure model, on the other hand, accepts grammatical structure and the type of ambiguous sentence as important while it does not emphasise the role of bias or context in processing of ambiguous sentences.

AN OVERVIEW OF SOME ISSUES IN AMBIGUITY

The experiments reviewed do not seem to suggest a clear choice among the hypotheses outlined earlier. The result of the few experiments supporting the unitary perception hypothesis can be attributed, among other things, to their failure to consider the bias levels of ambiguous sentences. One can argue that, if bias levels were systematically varied in these experiments, they would have shown the effect of ambiguity at least in the intermediate levels of bias. Besides, statistical support for the unitary perception hypothesis depends upon an impossible task of proving the null-hypothesis because it predicts no difference between ambiguous and unambiguous sentences. Turning now to the two variants of the exhaustive computation hypothesis, the weakness of one group of experiments seems to be the strength of the other. Experiments on the perceptual closure model vary the types of ambiguity and the point at which the task is initiated but fail to manipulate bias, context and set variables. Findings of the perceptual suppression experiments, on the other hand, are limited for their failure to consider the

structural types of ambiguity. It is, therefore, surprising that there has been no attempt so far to integrate these two models; rather there is a remarkable tendency to avoid the other model while discussing one. On the whole, it seems the nature of processing of ambiguous sentences can be related to a whole set of parameters and the interaction among them. These parameters can basically answer the questions 'when do we perceive ambiguity' or rather 'when do we process all the meanings of an ambiguous sentence' and not 'whether we compute all' the meanings of an ambiguous sentence'. It may turn out that we compute all the meanings of an ambiguous input under certain conditions and go along the garden path under certain others. A first step in building a theory of ambiguous sentence perception should therefore be, identifying and isolating various parameters associated with the processing of ambiguous sentences. It must also be pointed out here that most of the experiments discussed earlier consider ambiguity as a unitary experimental variable to which the different results may be causally connected. However, ambiguity may not be a single condition occurring in complete isolation. Rather, ambiguity might best identified as a whole set of conditions associated with multiple-meaning phenomenon. When ambiguity is experimentally manipulated what changes, is much more than the number of meanings of a sentence. The structure of a sentence, for example, may change in any attempt to vary the ambiguity condition. One should also guard against the

possibility of changing other semantic dimensions like the degree of concreteness and abstractness of a sentence, while changing the ambiguity. The role of some of the parameters of processing ambiguous sentences will now be discussed in trying to identify the problems involved.

Effects of Bias, Context, and Set

The effects of bias and context, as construed here, are slightly different from each other. Effect of context on comprehension of ambiguous sentences refers to the linguistic and the nonlinguistic situation within which a particular utterance occurs and which tends to favor some interpretation of the ambiguous utterance. Bias, on the other hand, refers to the strength of the meanings or their subjective probability relatively independent of any immediate context. For example, in a sentence like He took a right turn the meaning of the ambiguous term 'right' may be highly biased in favor of 'direction' without any other context in the sense that most people may accept this interpretation. However, a prior context, say, in the form of a sentence like He was taking a driving test would change such probability or bias in favor of a different interpretation. This is only a convenient way of distinguishing the two concepts and should not be taken as an absolute distinction. In fact, it has to be remembered that bias is nothing but an index of the context within which an utterance repeatedly occurs. The effect of set is

considered here as part of the context and as one that induces a perceptual tendency toward a particular meaning of an ambiguous sentence.

As pointed out earlier, bias, set and context seem to be quite important parameters in comprehension of ambiguous sentences and the perceptual closure model has been criticised for its failure to deal with these variables. The study by Olson and MacKay (1974) shows the importance of controlling for bias in experiments on ambiguity. Processing difficulty seems to be an inverted U-shaped function of the bias level of one meaning of ambiguous sentence. In the intermediate (50%) bias-level, i) the processing is most difficult and, ii) the probability of noticing the ambiguity is greater. The study by MacKay (1970) varied the bias of the ambiguous sentences simultaneously introducing a set in favor of one meaning. MacKay found that completion time was longer for the subjects seeing the unlikely meaning than for those seeing the likely meaning. MacKay interpreted this finding as showing that when subjects perceive the unlikely meaning they have to suppress the more likely meaning, a task which demands more time. In a study by Mohanty (Note 1) a group of subjects paraphrased 48 ambiguous sentences and then, rated them on a 7-point ambiguity scale (1:Non-ambiguous, 7:Ambiguous). Bias of the sentences, computed as the percentage of subjects who paraphrased the more frequently seen meaning, had a high negative correlation (r =-.90, df= 46, $p<.01$) with the average ambiguity ratings.

This shows that the higher the bias of an ambiguous sentence the less likely it is to be perceived as such. Six ambiguous lexical items were also presented to the subjects in the same study (Mohanty, Note 1) in the context of different sentences to see how such context affects the perception of lexically ambiguous sentences. The meaning of the items paraphrased by the subjects consistently changed congruent with the sentential context in which the ambiguous items appeared. For example, in the sentence The salesman wanted lots of the same size 52.38% of the subjects interpreted 'lots' as 'many', whereas in the sentence The realtor wanted lots of the same size, 88.23% interpreted the same lexical item as 'plots of land'. Although the study shows the effect of the context on interpretation of ambiguous sentences it says very little about its effect on the perceptual process itself.

In another study by Foss and Jenkins (1973) reaction time for target phonemes was longer following ambiguous words in both the neutral- and biased-context conditions. The results can be interpreted as showing that a pre-disambiguating context does not significantly change the processing difficulty due to ambiguity, although it might determine which of the meanings will be consciously perceived (Lackner & Garrett, 1972). In a study by Conrad (1974) both the meanings of ambiguous words were shown to be activated even when there were sufficient contextual information to indicate the desired meaning. The author

argued that "the context which is effective in disambiguating lexical ambiguities in the language has its effect only at a relatively late stage in the cognitive processing involved in language comprehension (p. 130)."

In terms of the effects of bias, the perceptual closure and the perceptual suppression models lead to certain conflicting predictions. According to the perceptual closure model both the meanings of an ambiguous sentence are processed but only one of them is finally perceived immediately at the end of the ambiguous clause. On the other hand, the perceptual suppression model predicts that at least in the intermediate range of bias both the meanings may be perceived and decision time for final acceptance of one of the meanings of ambiguous sentences depends upon the bias level. The stronger the bias of a meaning vis-a-vis the bias of the other meaning the sooner it is likely to be boosted and consciously perceived. In other words, the two models differ in their emphasis on the role of bias levels of the meanings in perception of ambiguous sentences. According to the perceptual closure model ambiguous sentences are more difficult to process regardless of the bias levels and this difficulty no longer exists once the end of the clause or the simple sentence is reached and a decision is made in favor of one meaning which is perceived. According to the perceptual suppression model, the fluctuation between the two alternative meanings continues beyond the end of the clause or simple sentence and the

duration of such fluctuation depends upon the bias levels of the meanings, processing being more difficult and longer when the meanings are of intermediate bias level. The perceptual suppression model therefore predicts that duration and difficulty of processing are greatest for ambiguous sentences in the middle bias range followed by ambiguous sentences of high bias and unambiguous sentences. If unambiguous sentences are considered to be sentences with 100% bias in favor of one meaning, one can simply say that bias level of the dominant meaning is inversely related to processing difficulty and duration.

Types of Ambiguity and their relative effects

When one considers the difference among lexical, surface structure and deep structure types of ambiguous sentences experiments have not shown any consistent results. In MacKay's (1966) study completion time for ambiguous sentences increased from lexical to surface structure and underlying structure ambiguity in that order. Similar results were obtained for ambiguity detection tasks in studies by MacKay and Bever (1967) and Foss (1970), and for picture verification tasks in the study by Foss et al. (1968). In Mistler-Lachman's (1972) study, time to produce a sentence following a given ambiguous sentence was minimum for lexical ambiguity and time for underlying and surface structure ambiguities did not differ. When the ambiguous sentences were given with context, the surface structure

ambiguity was least difficult and the lexical ambiguity did not differ from the underlying structure. In all these studies task performance under ambiguous sentence conditions were more difficult than unambiguous sentence condition, that is, the mean reaction times were longer for ambiguous sentences. But in the study of Bever et al. (1973) with a sentence production task, mean reaction time for lexically ambiguous sentences were more than that for unambiguous controls, whereas reaction time for sentences with both the types of structural ambiguity were faster than their corresponding unambiguous controls. In other words, structural ambiguity facilitated the task performances, underlying structure ambiguity yielding a greater facilitation. Within the ambiguous sentence condition, however, lexical ambiguity required less time followed by surface structure and deep structure ambiguity. In their second experiment with completion tasks Bever et al. (1973) found that underlying structure ambiguity increased processing difficulty significantly in incomplete clause conditions. In brief, the results of the second experiment were completely different from the first experiment; there was no facilitation and underlying structure ambiguity created maximum processing difficulty followed by surface structure and lexical ambiguity.

Bever et al. (1973) suggested a perceptual theory to resolve these inconsistent findings. According to these authors, when the task requirements are such that a response

based on perception of any meaning will do (as in case of a sentence production task) processing ceases when one meaning is consciously perceived. Since probability of perceiving one of the two meanings by a given time is greater than the probability of perceiving one meaning in isolation (see Bever et al. 1973, p. 280, for explanation), ambiguity will facilitate such task performance. Further, the degree of facilitation is determined by the relative independence of the two readings of an ambiguous sentence. Independence of the two meanings were tentatively defined in terms of the degree of dissimilarity between the two sets of perceptual mapping rules associated with the two meanins of ambiguity. In case of lexical ambiguity these rules are most similar (least independent) followed by surface structure and deep structure ambiguity, the two sets of mapping rules being the least similar (most independent) for the latter. Thus, it can be expected that in a task where any selection of meaning will do, facilitation with underlying structure is greatest followed by surface structure and lexical ambiguity in that order. But when the subjects have to make an active choice of response before the final interpretation (as in case of completion task) independence of both the perceptual mapping rules will no longer facilitate the task performance, rather it will pose a more difficult decision problem. In this case, the order of difficulty will be reversed for such tasks. To cut a long story short, following from this formulation one can hypothesise an

interaction between the type of ambiguity and the task characteristics. Bever et al. (1973) provide preliminary experimental support for this interaction effect.

There are, however, a number of problems with the outlined relationship between the ambiguity type, the experimental task, and computational difficulty. One can draw a basic distinction between lexical and structural types of ambiguity in the sense that lexical ambiguity is within the word and can occur without the context of a sentence, whereas structural ambiguity must necessarily occur within a sentence. It is therefore possible to think of ambiguity types as being distinct phenomena. Their comparability can be limited to the extent that any type of ambiguity is likely to affect perception of the meaning of a sentence one way or another and no specific claim can be made for any comparability regarding the manner in which these types of ambiguity affect such perceptual process. Further, there need not be any one-to-one relationship between the types of sentential ambiguity and the degree of independence between the two sets of mapping rules. Bever et al. (1973) suggest that within any single ambiguity type, the degree of independence may vary. The two should therefore, be kept separate and any further test of the proposed relationship should vary the degree of independence

controlling for the ambiguity type.[2] An equally serious limitation of this proposed relationship is that the bias and the task variables may confound the main issue in perception of different types of ambiguous sentences. Some problems related to the nature of the task will be discussed later.

The idea of the sentence types in a transformational model has been accepted a priori, as a viable parameter in analysing perception of ambiguous sentences. Accordingly, processing differences are expected between deep and surface structure ambiguities. However, such differences are not always found. Prideaux, Rowe, and Baker (Note 2) repeated an earlier experiment by MacKay et al. (1967) but did not get any difference between deep and surface structural ambiguities in terms of error scores in an ambiguity detection test. Prideaux (Note 3) has argued that both the structural types of ambiguity are resolvable at the surface level the only difference being in the labels attached to their bracketings. Fodor, Bever, and Garrett (1974) also suggested possible use of perceptual heuristics from the surface structure in processing the underlying structure of the sentence. Thus, it seems somewhat defensible to argue

---

[2] It is interesting to note that ambiguity type is a linguistic classification and as such its psychological reality may be as much in doubt as the reality of deep structure and surface structure distinction. Perceptual dependence between the two sets of mapping rules might as well prove to be a more useful formulation in explaining the processing difficulty in case of ambiguous sentences.

that distinction between sentence types following the transformational model may not be very useful for a theory of ambiguous sentence perception, and some of the ambiguity studies showing differences among the types of sentence ambiguity may have to be interpreted independently of such a grammatical model.

Nature of the Tasks and Psycholinguistic Processes

The perceptual closure model makes the task almost a crucial factor in predicting the outcome of any ambiguity experiment. However, as has been pointed out earlier, for the purpose of comparing the processing difficulty for ambiguous and unambiguous sentences the experimental task is not important in its own right; it is merely an indirect way of estimating the relative processing load on the subjects' cognitive mechanism at any given time and for a given type of sentence. Speed and accuracy measures for a variety of tasks like picture verification, phoneme monitoring, completion, association, response to probe words, and paraphrasing etc. have been used. Each of these tasks, in turn, can undergo variations in the time of initiation of the task performance, the length of presentation, and the time constraint on the response. All these tasks may call for different strategies and conflicting results may be attributed to the task variations rather than processing difficulties in ambiguous sentences. In fact, comparison of different tasks have yielded equivocal results. Bever et al.

(1973) showed that the point at which task performance is initiated is a crucial factor in ambiguity experiments. Carey et al. (1970) and Olson et al. (1973) concluded, on the other hand, that different tasks still yield comparable results. More recently, Cairns and Kamerman (1975) concluded that "the phoneme monitor task and the sentence completion task may not be used to test the same independent variable (p. 176)." In other words, different experimental tasks do not necessarily tap the same psycholinguistic process. Task variables may also be related to different depths of processing (Mistler-Lachman, 1972, 1975). Some tasks may induce a deeper comprehension in the subject than some others. Mistler-Lachman (1972) gave three language information processing tasks to measure levels of comprehension of ambiguous and unambiguous sentences. She concluded, "comprehension is apparently not a unitary process, but occurs at different depths or levels depending upon task demands (p. 614)." Carroll (1972) reviewed the methods and tasks employed to test comprehension and he suggested that the tasks vary to the extent that they do not yield comparable data in all cases. He suggested two criteria for a valid and reliable test of comprehension: i) the task should reflect pure comprehension and not any other skill like memory, guessing etc.; and ii) the task should yield consistent data on equivalent trials. Many of the tasks like completion, deliberate perception of ambiguity used in ambiguity experiments are not quite valid measures

of comprehension (Carroll, 1972). One may add to Carroll's comments that in the process of comprehension the listener is in fact trying to perceive the meaning of a sentence and not to perform an external task. Any task is an experimental tool designed to draw inference about the nature of processing and, by its very nature, the task limits the external validity of the conclusion arrived at. Ideally, therefore, one should be able to compare the effects of ambiguity types on processing difficulty in a situation closely resembling the normal speech comprehension. Task variables should not be allowed to play an important role unless it can be shown that the tasks reflect different conditions under which we normally hear and understand sentences as day-to-day speech units. Therefore, it seems essential that one should be able to infer processing difficulty from a measure which is independent of the processing load on the recipient of the language input and which does not interact with nor influence in any way the processing itself. A previous review of the topic (Mohanty, Note 1) has suggested that autonomic psychophysiological responses like Heart Rate (HR) and Galvanic Skin Response (GSR) seem quite suitable candidates for such measures.

Heart Rate as a measure of information processing. Psychophysiological measures of autonomic responses have recently been extensively used to infer processing load and difficulty levels in perceptual and cognitive tasks. Crucial

to such task performances are central processes like attention and arousal which have been shown to be closely related to autonomic functions. John and Beatrice Lacey and their co-workers (Lacey, 1959, 1967; Lacey, Kagan, Lacey, & Moss, 1963; Lacey & Lacey, 1970) have suggested that tasks which require the organism to attend to the external environment elicit decelerative heart rate, whereas tasks involving mental activity ('rejection of the environment') or attention to cognitive/perceptual information processing result in heart rate acceleration. Lacey's hypothesis has been supported in a number of subsequent experiments using a variety of cognitive and perceptual tasks. Lewis and Wilson (1970) showed that cardiac deceleration accompanied performance of a figure matching task during which subjects were engaged in scanning a picture. McCanne and Sandman (1974) showed that HR fluctuation was related to the nature of attention in a tachistoscopic perceptual task. Tursky, Schwartz and Crider (1970) demonstrated HR deceleration during the information-intake phase of a digit-transformation task and acceleration during the cognitive processing phase. The difficulty level of the task was positively related to the magnitude of HR fluctuation in either direction. In their study 15 subjects were tested in a time-locked digit-transformation task at two levels of difficulty. In the 'easy' condition subjects were asked to add zero to a series of four digits and in the difficult condition they were asked to add either three or four. The

results showed cardiac acceleration during cognitive processing. The magnitude of acceleration was also greater in the difficult task condition. Libby, Lacey, and Lacey (1973) showed greater deceleration of HR while subjects were attending to picture slides that were rated 'interesting, attention getting, unusual and arousing.' In Dahl and Spence's (1971) study mean HRs were recorded during sequences of perceptual-motor and cognitive tasks rated for task demand characteristics such as complexity, frequency, stimulus-transformation etc.. The correlation between mean HRs and task demand ratings were at least .91. Coles (1974) found that cardiac deceleration was related to the level of task difficulty in an osciloscopic detection task, consistent with the Laceys' intake-rejection hypothesis. In the study by Tursky et al. (1970), cardiac deceleration also occurred in the post-solution period following acceleration during information processing in the digit transformation task. In another study by Das and Bower (1973) subjects were tested in a probability learning task at two levels of uncertainty. Following 10 learning trials to build up an expectation, subjects were asked to anticipate which of the two events (x or y) would follow a cue word (Man). Probabilities of the two events were 0.90:0.10 in less uncertain condition and 0.70:0.30 in more uncertain conditions. Subjects' HR accelerated during anticipation period and decelerated during feedback that followed 5 seconds after subjects' guessing. The degree of HR change

was greater in the more uncertain task condition. The results are consistent with Lacey's hypothesis. A greater acceleration of HR in the 0.70:0.30 condition shows a greater cognitive effort in the anticipation period. In the more uncertain task condition there was also a greater attention to the outcome resulting in an increase in cardiac deceleration. An instrumental relationship between cardiac fluctuation and "the organism's receptivity to abberant stimulation and the organism's readiness to make effective responses to such stimulation (Lacey, 1972, p. 183)", has been shown to lack adequate support (Elliott, 1972, 1974; Hahn, 1973). But the proposed relationship of HR deceleration and acceleration with the level of the task complexity, attentional demands, and nature of the cognitive activities has been replicated in a number of studies (see Graham & Jackson, 1970; Gunn, Wolt, Block & Person, 1972; Hahn, 1973). HR has also been related with reaction time and other psychophysiological measures like skin conductance, respiration (Obrist, 1963), EMG (Obrist, Webb & Sutterer, 1969; Webb & Obrist, 1970). Besides Lacey's afferent feedback model, at least two other models have been proposed to explain the relationship between attention in different cognitive tasks and HR fluctuation. They are - the cardiac - somatic model of Obrist and Webb (1967, Obrist, Webb, Sutterer, & Howard, 1970) and the arousal model of Sokolov (1960, 1963). Discussion of these models is beyond the scope of the present review. However, it can be pointed out that

all these models accept the phenomena of HR deceleration and acceleration as associated with cognitive activities, but they disagree as to the function of such association and how it is mediated.

On the basis of the preceding review of the use of HR change measures it seems reasonable to conclude that these measures are sensitive enough to tap the difference between processing of ambiguous and unambiguous sentences. If, in fact, there is a greater processing load with ambiguity of sentences it should show up in terms of greater change of HR following the presentation of such sentences. Psychophysiological measures like HR and GSR have been used quite extensively in studies of cognitive processing. But their use is relatively new in the fields of verbal information processing and psycholinguistics. However, there have been some recent attempts to use other psychophysiological measures like EMG, EEG, Eye Movement, and Pupillary Reaction in studies of meaning (Osgood & McGuigan, 1973), imagery in verbal processing (Paivio, 1973), covert language behavior (McGuigan, 1973) and other language related processes. In a very recent study, Shangi (Note 4) used HR measures to test the levels of processing model of Craik and Lockhart (1972). In this study different depths of processing were induced by giving the subjects, prior to presentation of stimulus words, orienting questions about their type script (physical level), sound characteristics (phonemic level), and meaning (semantic

level). Subjects' HR was monitored throughout the experiment. Second-by-second HR changes and HR acceleration scores differentiated the three levels of processing.

Stennett (1966) outlined two criteria for a good peripheral indicator of arousal in information processing and attentional tasks. They are i) the change in peripheral measure related to change in the state of the organism should be detectable, ii) degree of change in the organism should be related to the degree of change in the peripheral measure. HR measures seem to satisfy these conditions. However, at this stage their use in psycholinguistic research is yet to be demonstrated and this study may be considered an exploratory step in that direction.

In conclusion, the preceding review indicates that the current state of psycholinguistic accounts of ambiguous sentence perception leaves a lot to be desired. The main debate between the unitary perception and the exhaustive computation hypotheses has been whether ambiguity makes the perception of sentences more complex. The studies reviewed have generally tried to compare some task performance under conditions of ambiguous and unambiguous sentence processing. The common assumption has been that if processing of a sentence is more complex any simultaneous task performance (usually involving reaction time measures in some form) would be less efficient. As discussed earlier, this methodology not only creates a problem of validity, it also

complicates the main issue by raising questions about the task artifact, interaction of the task with processing of sentences, point of onset of the task performance and so on. Obviously, the issue is not under what kind of tasks but under what conditions is the processing of ambiguous sentences more complicated. Although by no means exhaustive, two sets of factors were discussed as possible parameters of processing ambiguous sentences -- the bias, context, and set factors affecting the subjective probability or strength of the meanings and the linguistic type of ambiguous sentences as a factor related to the perceptual process in sentence comprehension. The major differences and similarities among the three models of ambiguous sentence perception are summarised in Appendix C. A psycholinguistic account of ambiguous sentence perception, it seems, should involve more than a choice among these models because it is possible that under some conditions of bias and sentence type ambiguous sentences are perceived unitarily where as under certain others both meanings are computed. Finally, it was argued that use of psychophysiological measures like HR changes should provide a methodological improvement because these seem to be adequate to indicate differences in the degree of perceptual complexity without actually interfering with the perceptual process itself. The purpose of the present investigation, therefore, is to test, by using measures of heart rate change as indices of processing difficulty, the unitary perception and the exhaustive computation hypotheses

under different conditions of bias (Experiment 1) and sentence type (Experiment 2). Some predictions of the perceptual suppression and the perceptual closure models were also tested.

CHAPTER II

EXPERIMENT 1

Rationale and hypotheses

Comparison of ambiguous and unambiguous sentences, it seems, cannot yield a clear choice among the alternative models of ambiguous sentence perception without due consideration of the effect of context or the set of factors that tend to make any ambiguous sentence biased toward one of the meanings. As discussed earlier, when an ambiguous sentence is highly biased in favor of one meaning, its perception perhaps closely resembles that of any unambiguous sentence. On the other hand, when there is relatively equal bias for both the meanings the perception of the sentence, more likely, follows an exhaustive computation process; both the meanings are considered prior to a choice among them. Although there are some studies to indirectly support this prediction it has, so far, not been put to a direct test. In the present experiment bias of the lexically ambiguous sentences was varied to test this prediction. Bias of an ambiguous sentence was defined as the percentage of native users of language likely to report perceiving its more frequently perceived meaning. In other words, if 55% of the native users of language report seeing meaning A of a sentence X and the remaining 45% report seeing its meaning B

then the bias of the sentence is indicated by the greater of the two percentage scores, i.e., 55% in this case. Thus a sentence with two potential meanings can theoretically have a minimum bias of 50% and a maximum of 100%.

When comparing the comprehension difficulty of ambiguous and unambiguous sentences, studies have generally used reaction time and accuracy measures in various task performances. It was pointed out earlier that such tasks may not be quite suitable particularly in case of trying to determine the effects of ambiguity on processing of sentences. Psychophysiological measures like heart rate acceleration and deceleration were suggested as suitable for this purpose. These measures appear to be quite reliable indicators of cognitive activity and, further, unlike other task performance measures, they do not, in any way, interfere with the cognitive activity itself. Acceleration of heart rate following the presentation of a stimulus has been known to be related to cognitive information processing. The degree of such acceleration is also related to the degree of difficulty of the information processed. The heart rate deceleration following the initial acceleration seems to have a similar relationship with the nature of cognitive activity. As discussed earlier, cardiac deceleration follows acceleration in problem solution tasks (e.g. Tursky et. al 1970) and in tasks involving uncertainty (e.g. Das & Bower, 1973). It was pointed out that such deceleration is a result of subjects' attention to or

preparation for external events like feedback. When subjects are required to perform a task following the stimulus, cardiac deceleration is also observed as a preparatory response (Coles & Duncan-Johnson, 1975). In the fore-period of a reaction time task, for example, greater deceleration of HR is noticed as the task becomes more demanding (Coles, 1974). In this study, HR acceleration and deceleration were, therefore, used as indices of the processing difficulty of ambiguous and unambiguous sentences.

If, as pointed out earlier, only one meaning of ambiguous sentences in high-bias condition is processed the degree of HR acceleration and deceleration should not differ significantly from those in unambiguous sentence condition. However, in low-bias condition the degree of HR acceleration and deceleration should be greater for ambiguous sentences than for unambiguous ones. The following were, therefore, hypothesized:

> Hypothesis 1.1: HR acceleration following the presentation of ambiguous sentences is significantly greater than that following unambiguous sentences when the ambiguous sentences are of the low-bias condition, but when they are of the high-bias condition the difference is not significant.
>
> Hypothesis 1.2: HR deceleration following the presentation of ambiguous sentences is significantly greater than that following unambiguous sentences when the ambiguous sentences are of the low-bias condition, but when they are of the high-bias condition the difference is not significant.

Briefly, then, significant Ambiguity X Bias interaction

effects were hypothesised in regard to the HR acceleration and deceleration measures. Such interaction would support a dual-process model -- unitary perception for the high-bias ambiguous sentences and exhaustive computation for the low-bias ones.

Assuming that such is the case, there is still no way of deciding whether the exhaustive computation, whenever it occurs, follows the perceptual closure model or the perceptual suppression model. A probe-word-technique was used to obtain more information about the nature of the perceptual process and to possibly test some predictions of the perceptual closure and the perceptual suppression models. The technique involves presenting probe words following the sentences and asking the subjects to decide if the word is related to the meaning of the sentence and to make a choice repsonse. Reaction time to different types of probe words is measured and compared. Shanon's (1974) method of giving probe words with different levels of relevance to the meaning(s) of the sentences was followed except that a longer interval (21 seconds) between the sentence offset and the probe word was given to make sure that the task does not interfere with at least an initial processing of the sentence. Further, an additional probe word category was used giving words related to both the meanings of ambiguous sentences.

When people are asked to judge if a probe word is

related to the meaning of a sentence, congruent with the three models of ambiguous sentences there are three possible ways in which such judgement can be made:

A) According to the unitary perception model, people may process an ambiguous sentence just as they would have processed an unambiguous one. Only one meaning is processed, retained and then compared with the probe word that follows the sentence. The interpretation that is perceived and retained is usually the one toward which the sentence is biased. However, if the probe word is not related to the more probable meaning but related to the less probable meaning instead, it provides a new contextual information which disconfirms the perceived interpretation. In such a case, the sentence has to be reprocessed. For example when the following sentence

(1) The pitcher is full.

is followed by a probe word baseball, a new context is provided which changes the initial bias of the sentence and which, according to the unitary perception model, triggers a reprocessing of the sentence. Further, since the probe word baseball provides its own context, the initial bias of the sentence is no longer important; the sentence is reprocessed regardless of its initial bias. The time required to reprocess the sentence and then to respond to the probe word therefore does not depend on the initial bias of the sentence. In other words, RT to probe words related to the non-dominant meaning of ambiguous sentences should be longer

than the RT to unambiguous sentences with the same response (yes/no) category but independent of the bias level of the sentences. For all other types of probe words the RTs for ambiguous and unambiguous sentences should be the same for similar (yes/no) response category regardless of the bias condition. Thus, if the unitary perception model is valid, there should be --

i) no effect of bias on RT to probe words,

ii) no difference between RTs to ambiguous and unambiguous sentences of similar response type (yes/no) except for the RT to probe words related to the non-dominant meaning of the ambiguous sentences which should be greater than the RT for the probe words related to the meaning of unambiguous sentences.

B) The second possible stragegy follows the perceptual closure model. This model would suggest that regardless of their bias level, both the meanings of ambiguous sentences are considered before acceptance of one meaning, which is then retained and compared with the probe word. When a probe word is related to the meaning which is less likely, and perhaps discarded for that reason, a context in favor of that meaning is provided. However, unlike the unitary perception model, since both meanings have already been computed, no extra processing time should be involved in comparing the probe word with the context related meaning of the ambiguous sentence. In the case of the probe word baseball to the sentence (1), the perceptual closure model would suggest that both meanings of ambiguous lexical item pitcher have been computed regardless of the context or bias

of the sentence; the sentence, therefore, does not have to be reprocessed any more. On the other hand, when the probe word is unrelated to either of the meanings of ambiguous sentences comparison has to be made with both the perceived interpretations before a 'no' response is given. The RT to unrelated probe words, therefore, should be greater for the ambiguous sentences than for the unambiguous ones whereas the RT to related probe words should not be affected by sentence ambiguity. In other words, if the perceptual closure model is valid, there should be --

i) no effect of bias on the RT to probe words,

ii) no difference between the RT to ambiguous and unambiguous sentences when the probe words are related (to the dominant meaning or to both the meanings, in case of ambiguous sentences),

and further,

iii) the RT to unrelated probe words should be greater for the ambiguous sentences than for the unambiguous ones

C) Finally, according to the perceptual suppression model, both the meanings of ambiguous sentences are computed and people continue to fluctuate from one meaning to the other. In an experimental situation this fluctuation continues until, at least, a task performance. The probe words are compared first with the dominant or the more probable meaning and the processing ceases if such comparison yields a positive match. However, if the first meaning does not match the probe word another comparison is made with the other meaning which is already computed but suppressed by

the dominant meaning. For this comparison the dominant meaning has now to be suppressed so that the other meaning can be consciously perceived and compared with the probe word. This process of suppression should be easier in the low-bias condition, i.e., when the meanings have relatively equal probability, and more difficult in the high bias condition in which the dominant meaning is much stronger. In other words, given a probe word following an ambiguous sentence, we first compare the probe word with the more likely meaning of the ambiguous sentence and if the comparison is negative we compare it with the other (less likely) meaning. But in order to do so, according to the perceptual suppression model, we must suppress the more likely meaning. If the meaning first compared has a bias of, say, 50-60% its suppression is easier than if it has a bias of 80-90%. Thus, the RT to unrelated probe words should be greater for the high-bias ambiguous sentences than that for the low-bias ambiguous sentences which, in turn, should be greater than the unambiguous ones. Similarly, when the probe words are related to the less probable meaning of the ambiguous sentences the RT should be greater in the high-bias condition than in the low-bias condition. In other words, if the perceptual suppression model is true then,

i) the RT to the unrelated probe words should be longest for the high bias ambiguous sentences followed by the low-bias ambiguous sentences and the unambiguous sentences, in that order,

ii) the RT to the probe words related to the less dominant meaning of ambiguous sentences should be greater in the high-bias condition than the low-

bias condition,

iii) there should be no difference among the RTs to probe words related to the meaning of unambiguous sentences, and to the dominant meaning or to both meanings of ambiguous sentences.

The three models of ambiguous sentence processing, thus, lead to different sets of predictions with regard to the RTs to the probe words of various types. According to the unitary perception and the perceptual closure models, bias level of the ambiguous sentences should have no effect on the RT to probe words. According to the perceptual suppression model, on the other hand, bias of the ambiguous sentences is a significant variable for the RT when the probe words are either unrelated or related only to the less probable meaning of ambiguous sentences. Further, according to the unitary perception model, the RT to the probe words related to the less dominant meaning of ambiguous sentences of any bias level should be greater than the RT to the probe words related to the unambiguous sentences, whereas, according to the perceptual closure model, the RT in the ambiguous sentence condition should be greater than the unambiguous sentence condition only when the probe words are unrelated to the meaning(s) of the sentences. The probe-word technique was thus used in the present experiment to test the predictions of the three models as discussed earlier.

Method

Stimulus sentences and probe words

A) Selection of Sentences -- a pilot study

Six high- and six low-bias lexically ambiguous sentences and their respective pair of control sentences were used in this experiment. The sentences were taken from a previous study (Mohanty, Note 1). One of the purposes of this study was to select the list of sentences for Experiment 1 and another list of 18 low-bias ambiguous sentences -- six each from the lexical, deep structure and surface structure types -- and their respective pair of controls for Experiment 2. The study for selection of sentences was conducted in two phases. In phase 1 bias ratings were obtained for a number of ambiguous sentences and in phase 2 ambiguous sentences selected from phase 1 and their control sentences were rated and matched on Semantic Differential (SD) scales.

Bias rating of ambiguous sentences. A list of 100 ambiguous sentences of the three linguistic types was prepared. Most of the sentences were used in previous studies on sentence ambiguity. In some cases the original sentences had to be slightly modified to conform to a standard length of seven to nine words. The list was given to two independent judges to select lexical, surface structure and deep structure types of ambiguous sentences more likely to be of the low-

bias (50-70%) range and lexically ambiguous sentences of the high-bias (more than 80%) range. The judges were also asked to discard sentences of doubtful grammaticality, sentences with more than two meanings (multiply ambiguous), clumsy sentences - ones highly unlikely to appear in a normal conversation and also sentences likely to have extreme scores on Semantic Differential (SD) scales. On the basis of complete inter-judge agreement 48 ambiguous sentences -- 25 lexical, 12 surface structure, and 11 deep structure types -- were selected. These sentences and 24 unambiguous ones were divided into four randomised lists with 12 ambiguous and six unambiguous sentences in each. The unambiguous sentences were, in fact, controls for 24 of the ambiguous sentences prepared by changing only the ambiguous terms. Sentences from the ambiguous-control pairs appeared in separate lists. The four lists were then given in a Sentence Interpretation and Ambiguity Rating Questionnaire (Appendix A) to a sample of 163 undergraduate students of the University of Alberta. Each student got one of the four lists at random. There were 42 responses for Lists 1 and 2 each, 40 for List 3 and 39 for List 4. In part I of the questionnaire the students were asked to paraphrase the meaning of the sentences and in part II they were asked to indicate whether or not the sentences were ambiguous and if so, to paraphrase the other meaning of the sentences. They were also asked to rate the sentences on a 7-point scale of ambiguity (1 : unambiguous - 7 : ambiguous). The subjects

took roughly one hour each to respond to the questionnaire. The meaning paraphrased first (in part I) were scored as indicating one of the two meanings of the ambiguous sentences. Responses which failed to indicate a meaning clearly were discarded. Bias of the ambiguous sentences was computed as the percentage of responses indicating the meaning paraphrased by the majority. For example, if 30 out of 40 acceptable paraphrases indicated meaning A of an ambiguous sentence the rest indicating its meaning B, then the bias of the sentence was taken to be 75%. The lexical, surface structure, and deep structure types of ambiguous sentences with bias scores between 50-70% and only lexically ambiguous sentences with bias scores above 80% were selected as low and high bias sentences respectively and were used in the next phase of the study. In total 31 low-bias ambiguous sentences -- 14 lexical, 8 surface structure, and 9 deep structure types -- and 8 high bias lexically ambiguous sentences were taken for rating on SD scales.

Rating on Semantic Differential scales. For each of the 39 ambiguous sentences a pair of unambiguous control sentences was prepared by making minimum change in the ambiguous part of the sentences. Each of the two control sentences represented one reading of the corresponding ambiguous sentence. For example, the controls for The driver took a right turn at the intersection were -- The driver took a correct turn at the intersection and The driver took a left turn at the intersection. The length of the control

sentences were also limited to 7-9 words. The ambiguous and the control sentences were divided into four lists with 29 sentences each in three lists and 30 in the fourth. The ambiguous and the corresponding control sentences were put into separate lists. For every sentence two appropriate scales from each of Osgood's (Osgood, Suci, & Tannenbaum 1957) three dimensions of meaning (viz. Evaluation e.g. pleasant-unpleasant, Potency e.g. strong-weak, and Activity e.g. active-inactive) were selected along with two other scales for abstractness (concrete-abstract) and specificity (general-specific). All of the eight scales for each sentence were given in randomised order. The same scales were used for the ambiguous and corresponding control sentences. The subjects were given standard instruction to rate the meaning of the sentences on each of the 7-point scales. Subjects were 140 undergraduate students (other than the ones used in phase 1) -- 35 for each of the four lists. They took approximately one hour each to complete the rating scales. Average ratings on the eight scales for the ambiguous and their control sentences were computed. The sentences finally selected for the two experiments were within an average rating score of 0 ± 1.5 for each of the eight scales. In other words, the sentences were very close to the neutral points in respect to these scales. Further, the maximum difference in rating scores on each scale within a set of ambiguous and control sentences was not more than 0.5, a difference, which according to Osgood, May, and Miron

(1975) is not significant. On this basis the ambiguous and control sentences were assumed to be matched with respect to these indicators of meaning.

To sum up, the sentences selected for the experiments 1 and 2 meet the following criteria:

i) length of 8 ± 1 words,

ii) neutrality in regard to the E, P, and A dimensions (average rating: 0 ± 1.5),

iii) neutrality in regard to generality and abstractness (average rating: 0 ± 1.5).

Further, the ambiguous sentences were

iv) within a specified range of bias (low-bias: 50-70% and high-bias: more than 80%)

and v) matched with their respective control sentences for sentence structure, length, and average ratings on eight different scales.

B) Selection of Probe Words

Six types of probe words[3] were used in the experiment, viz. the ones 1) related to the meaning of the unambiguous sentences (Y:un) (e.g. Sylvia dropped a playing card on the table. -- GAME), 2) not related to the meaning of the unambiguous sentences (N:un) (e.g. Sylvia dropped a playing card on the table. -- BOY), 3) related to both the meanings of the ambiguous sentences (Y:b) (e.g. The roar of the fans disturbed the chess players. -- CONCENTRATION), 4) related only to the dominant meaning of the ambiguous sentences

---

[3] See Appendix B for a list of all the probe words used.

(Y:d) (e.g. Sylvia dropped a spade on the table. -- GAME), 5) related only to the non-dominant meaning of the ambiguous sentences (Y:n-d) (e.g. The lawyer insisted that the charge was unjust. -- COSTLY), and 6) not related to either meaning of the ambiguous sentences (N:am) (e.g. The chairman of the department has two appointments. -- MOUNTAIN). Within each bias level the number of probe words for ambiguous sentences were balanced between related - unrelated types, i.e., three of the six ambiguous sentences in each bias level were followed by unrelated probe words and the rest by related probe words (one from each type, viz., Y:b, Y:d, Y:n-d). The probe words for the ambiguous sentences were also used for one of the corresponding pair of controls. The related-unrelated probe words (i.e., the yes-no response types) were also balanced, within each list, for ambiguous sentences of different bias levels and for unambiguous sentences to prevent any possible response bias. Within the lists, the three types of related probe words to ambiguous sentences, however, were not balanced. All the probe words were selected in consultation with three fellow graduate students who agreed on the relationship of the probe words to the sentences.

Design of the experiment

The ambiguous sentences were divided into three lists -- each with a cluster of two high-bias and two low-bias sentences. The two unambiguous (control) sentences were

randomly assigned to two lists other than the one containing the same ambiguous sentence. For example, the following set of sentences -

(2) The driver took a right turn at the intersection. (Ambiguous - High-bias).
(3) The driver took a correct turn at the intersection. (Control 1).
(4) The driver took a left turn at the intersection. (Control 2).

were put into separate lists (lists 2, 1 and 3, respectively, in this case). Thus, the sentences were so arranged that within each bias condition, a list of sentences had a cluster of two ambiguous sentences, a cluster of two unambiguous (control) sentences corresponding to the ambiguous sentences in the second list, and another cluster of two (unambiguous) controls corresponding to the ambiguous sentences in the third list. In fact, the clusters of two sentences each were arranged in Latin square design presented in Table 1.

Winer's Plan 12 repeated-measures Latin square design (Winer, 1971, p. 745) was followed with the bias (B), ambiguity (A), and sentence-cluster (C) factors repeated and the subjects (P) nested within the lists/groups.* A

* It must be pointed out here that the clusters are actually the means of two sentence-scores. Since the reliability of the means is greater than the reliability of the raw-scores the design has some advantage. On the other hand, there is also a loss of the power of statistical tests due to a decrease in the degrees of freedom with the use of mean scores instead of raw-scores. In this design reliability of the measures was preferred to a greater power of the statistical tests.

TABLE 1
Design for the Experiment 1

		High-bias b^1			Low-bias b^2		
		Ambiguous a.1	Unambiguous Control 1 a.2	Unambiguous Control 2 a.3	Ambiguous a.1	Unambiguous Control 1 a.2	Unambiguous Control 2 a.3
Group 1 (List 1)	P.1 P.2 . . . P.10	C (2)	C (1)	C (3)	C (2)	C (1)	C (3)
Group 2 (List 2)	P.11 P.12 . . . P.20	C (3)	C (2)	C (1)	C (3)	C (2)	C (1)
Group 3 (List 3)	P.21 P.22 . . . P.30	C (1)	C (3)	C (2)	C (1)	C (3)	C (2)

Note 1: C refers to a cluster of two sentences. Thus, C(1) under $b^1a.2$ refers to the cluster of unambiguous control sentences corresponding to the high-bias ambiguous sentences in List 3.

Note 2: P refers to the people nested within groups.

limitation of this design, as of any fractional replication of factorial design, is that full information on some of the interaction effects cannot be obtained. In this case, only partial information was available on Ambiguity (A) x Sentence-cluster (C), and Ambiguity (A) x Sentence-cluster (C) x Bias (B) interactions. These interactions were considered relatively inconsequential for testing the main hypotheses of the experiment. Full information, however, was obtained on Ambiguity x Bias, Bias x Group, and Bias x Cluster interaction effects. Since the experiments on language and verbal behavior have been criticized (see Clark, 1973) for the confounding effects of the specific sample of sentences, words or any linguistic unit used in the experiments, one advantage of this design is that it allows separating the variance due to the sentence-clusters as a main factor (i.e., the variance of the means for Clusters 1, 2, and 3 - C1, C2, C3 in the design table.). Tests of the ambiguity and bias main effects could, therefore, be made relatively independent of such effect. Further, in this design, each group of subjects received a randomised list of sentences consisting of two high-bias, two low-bias ambiguous sentences, and eight unambiguous control sentences. Only a third of the sentences given to the subjects was ambiguous compared to at least a half in other studies, thus, reducing considerably the possible effects of stimulus bias.

An experimental session consisted of 12 trials - one

for each stimulus sentence in the list to which the subjects were randomly assigned. Each sentence was visually presented through a slide projector for five seconds, followed by an interval of 15 seconds. At the end of this interval a tone was given for one second as a warning signal for the probe word. Five seconds after the offset of the warning signal the probe word corresponding to the stimulus sentence was exposed for four seconds. The subjects were given prior instruction to indicate by pressing one of the two buttons whether or not the word is related to the meaning of the sentence. The subjects' responses were recorded only if they occurred within four seconds of the onset of the probe words. The intertrial interval was 20 seconds.

The intervals between the different events in a trial were decided by a pilot study with 15 subjects. For the first five subjects the duration of the presentation of the stimuli and the intervals were varied from trial to trial to find out if the intervals were comfortable but not too long. For the next five subjects the inter-event intervals were fixed. The heart-rate changes and the reaction times of these subjects were examined to decide the optimum intervals. On the basis of these data the interval between the offset of the stimulus sentences and the onset of the warning signal was reduced from 20 to 15 seconds as the subjects' heart rate seemed to return close to prestimulus levels in about 10-12 seconds. The exposure time for the probe words was also reduced from five to four seconds since

none of the subjects took more than three seconds to respond. The last five subjects for the pilot study were tested as practice runs for the main experiment.

Subjects

Thirty male undergraduate student volunteers from the University of Alberta served as subjects for this experiment and two others were dropped -- one because of a fire alarm in the building during the experiment and the other due to mechanical failure of the polygraph. All the subjects were English speaking unilinguals. Their average age was 20.23 years and the range was from 18 to 26 years. All the subjects were right handed and reported no sensory-motor impairment. They were paid $2.50 each for participation in the experiment.

Apparatus

A Hewlett-Packard polygraph model 1500 with an integrated cardiotachometer was used to obtain, on three channels, subjects' heart rate, galvanic skin responses, and a record of event onsets in a trial continuum. The recordings were made continuously throughout the experimental session on polygraph paper running at a constant speed of 5 mm./second.

The onset and offset of events and the time intervals were controlled by Lafayette Instruments eight-bank

Programmer Timer. The stimulus sentences and the probe words were projected on the screen by a Lehigh Valley Electronics 111-10 programmable carousel projector with a built in solenoid operated shutter. It was also slightly modified to allow the timer to automatically advance the slides at the end of each exposure. The tone (1000 Hz, 70 db) was generated by a Lafayette Instruments Audio-signal Generator connected to the timer and to a speaker-amplifier in the experiment room.

The device to measure the subjects' reaction times was switched on automatically by the timer which also began simultaneously the exposure of the probe-word-slide by opening the shutter in the slide projector. The reaction time device consisted of an electronic stop clock, a response apparatus with a red and a green button on a panel attached to the arm rest of the chair on which the subjects were seated for the experiment. The subjects were instructed to press the green button to indicate 'yes' responses and the red button to indicate 'no' responses. This button-pressing response could stop the clock and switch on a light the same color as the button pressed. The duration from the onset of the stop clock and the probe word slide to the button-pressing response was measured in milliseconds. The reaction time and the response category indicated by the color of the light were recorded trial-by-trial by one of the two experimenters. The stop clock had to be manually reset after every trial.

The stimulus sentences and the probe words were projected at eye level on a projection screen placed four feet directly in front of the subjects. The projection was done from the control chamber through a one-way glass window in the experiment room.

Procedure

The subjects were tested individually in an electrically shielded and soundproof room with a controlled temperature of 68°F. This room, designed primarily for psychophysiological testing, is adjacent to another control chamber in which the polygraph and other necessary equipment were located.

The subjects were asked to sit comfortably in a semi-reclining high-back chair. They were informed that the experiment was concerned with adult's understanding of English sentences. The nature and the function of the electrodes to measure the heart rate and GSR were also explained to them. The response panel was adjusted to the subjects' convenience and on the side of their preferred hands. Then the electrodes were properly placed and the subjects were asked to sit relaxed on the chair without much movement. They were left alone for about two minutes during which the polygraph record was checked. Instructions were given after the subjects' heart rate stabilised. All the subjects were informed about the sequence of events and the

experimental task. They were asked to try to understand the sentence when it came on the screen and to get ready for the probe word on hearing the warning signal. They were asked to decide, as soon as the probe word came on, if the word was related to the meaning of the sentence and to press a green button for 'yes' responses and a red for 'no' responses. They were given two examples and asked to demonstrate their responses. They were also instructed to respond promptly and accurately and were told that there would be a few trials in the experiment. They were asked if they had any doubts and then left alone in the experiment room when they understood their task.

Two experimenters conducted the experiment -- one monitored the polygraph and observed the subject through the one-way glass and the other monitored the programmed timer which controlled the equipment and recorded responses and reaction time trial-by-trial. There was a brief post-experiment interview in which the subjects were asked about the experiment and a few other questions about the sentences and the probe words given. The entire session lasted approximately 45 minutes for each subject.

Subjects were randomly assigned to one of the lists on arrival in the laboratory. The testings were also balanced over the fore-noon and after-noon sessions.

Results and Discussion

The heart rate and the reaction time data were analysed separately. The average second-by-second changes in HR for 18 seconds following the onset of sentences were computed. Percentages of HR acceleration and deceleration were analysed and related to the processing of high- and low-bias ambiguous sentences and unambiguous sentences. The mean RTs in different sentence-conditions were compared. Further, the mean RTs to various probe-word categories were also analysed to see how well they fit the predicitons of the three models of ambiguous sentence perception. The details of the analyses for HR and RT data are presented next.

Heart Rate

Each subject's record of heart rate (HR) was scored for second-by-second beats per minute (BPM) two seconds before the stimulus sentence and 18 seconds from its onset for each trial. The average of the BPM scores for two seconds prior to the onset of the stimulus sentence in each trial was taken as the subjects' pre-stimulus HR (Pre HR). Percentage of acceleration score (Acce %) was defined as the percentage of maximum increase over the pre-stimulus HR (Pre HR) within 10 seconds after the stimulus onset. Thus, if the maximum BPM within 10 seconds after the onset of the stimulus sentence is Maxi-HR, then

$$\text{ACCE \%} = \frac{\text{Maxi HR} - \text{Pre HR}}{\text{Pre HR}} \times 100.$$

Similarly, the percentage of deceleration score (Dece %) was defined as the percentage of maximum decrease over the pre-stimulus HR (Pre HR) within 4-14 seconds after the onset of the stimulus onset. Thus, if the maximum BPM within 4-14 seconds after the onset of the stimulus sentence is Mini HR, then

$$\text{DECE \%} = \frac{\text{Pre HR} - \text{Mini HR}}{\text{Pre HR}} \times 100.$$

The time intervals for the calculation of the percentages of acceleration and deceleration were determined on the basis of an examination of the average HR change curves. The pre-stimulus HR, the percentage of acceleration and deceleration scores, and the second-by-second change scores were computed by a Heart Rate Blocking and Analysis Program (Bower, Note 5) which was specially modified for the present data analysis. The mean of the pre-stimulus HRs for the sample was 76.61. There was no significant difference among the three groups in regard to the pre-stimulus HRs ($F < 1$). Figure 1 shows the average second-by-second BPM changes over the pre-stimulus HR for the unambiguous, the high bias ambiguous and the unambiguous sentences. The positive change scores indicate acceleration and the negative scores indicate deceleration of HR over the prestimulus level. While the major accelerative and decelerative patterns of change following the onset of the stimulus sentences remain generally comparable in the three conditions, they are most accentuated for the low bias ambiguous sentences.

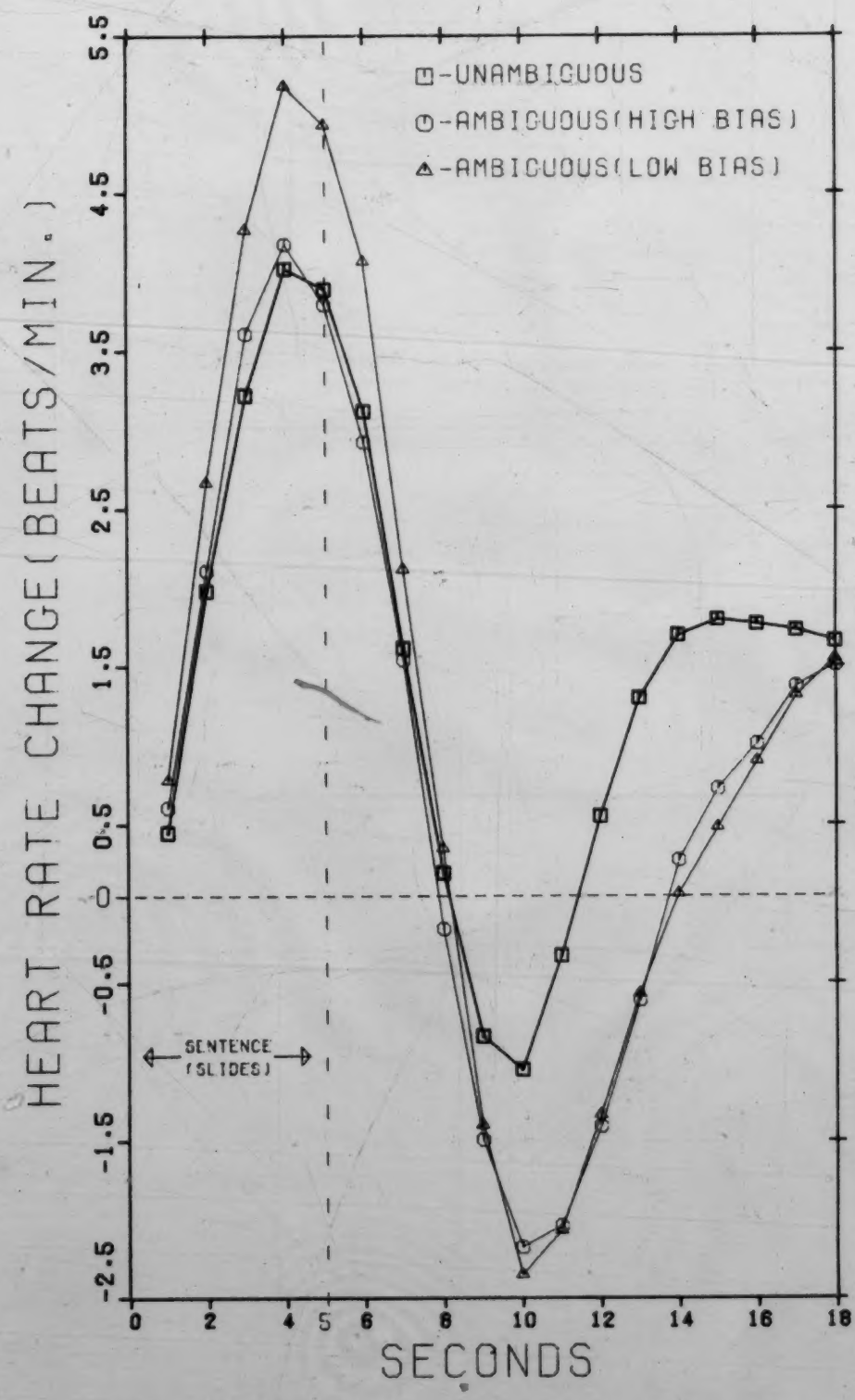

Figure 1. Mean Second-by-Second Changes in Heart Rate

Each of the analyses of variance for Groups X Cluster X Ambiguity X Bias Latin square repeated measures design was carried out in two stages. In stage one, following Winer's (1971, Pp. 745-748) suggestion, one of the dimensions of Latin square viz., the sentence-cluster (C) factor, was disregarded and a 3(Groups) X 3(Ambiguity) X 2(Bias) analysis of variance was carried out with the Ambiguity and Bias factors repeated and subjects nested within the groups. In stage two, a two-way (Bias X Sentence-cluster) analysis of variance was carried out. The sources of variance and their respective sums of squares in these two analyses of variance were then broken down to obtain the sums of squares for the main analysis of variance in the Latin square design.

HR Acceleration. The results of the analysis of variance for the percentage of HR acceleration scores are presented in Table 2. The mean percentage of acceleration for the low- and high-bias ambiguous sentences and for all the unambiguous sentences were (in control 1 and 2 conditions) 8.947, 7.402, and 7.288 respectively. As predicted, Ambiguity X Bias interaction effect was significant, $F(2,54) = 6.17$, $p < .01$. The interaction effect was further examined by a Scheffe test of planned contrasts (Winer, 1971). The difference between the mean percentage of HR acceleration for the ambiguous and the corresponding unambiguous control sentence-clusters was significantly greater in the low bias condition than the high bias

Table 2
ANOVA summary table
for
the Percentage of HR Acceleration scores

Source	df	MS	F
Between People	29		
Groups (G)	2	3.084	0.08
People within Gr. (P:G)	27	36.560	
Within People	150		
Ambiguity (A)	2	16.234	3.82*
Sentence-Cluster (C)	2	0.332	0.08
(AC)[1]	2	1.931	0.45
Residual (1)	54	4.250	
Bias (B)	1	4.156	1.45
B X G	2	1.648	0.58
Residual (2)	27	2.857	
B X C	2	0.361	0.13
A X B	2	17.709	6.17**
(AC)[1] X B	2	0.861	0.30
Residual (3)	54	2.869	

Note: All the Residual sums of squares and their respective degrees of freedom were pooled to obtain the Pooled MS error which was used for Scheffe tests. Pooled MS error = 3.419, df = 135.
*p < .05 **p < .01

condition, F[s] (1,135) = 10.13, p < .01. This would account for the Ambiguity X Bias interaction effect. As Table 2 shows the ambiguity main effect was also significant, F (2,54) = 3.82, p < .05. On further Scheffe tests, it was found out that the mean percentage of acceleration for low bias ambiguous sentence-clusters was significantly greater than the mean for their corresponding controls F (1,135) = 19.29, P < .01, whereas the mean of the high bias ambiguous sentence-clusters did not differ significantly from the mean of their respective controls (P<1). Thus, the Scheffe tests for specific Ambiguity X Bias interaction effect and the ambiguity main effects lend further support to Hypothesis 1.1. The complexity of sentence perception, as indicated by the percentage of HR acceleration seems to be greater for the low bias ambiguous sentences compared to their respective controls whereas high bias ambiguous sentences do not differ from their unambiguous controls. In other words, the analysis of variance and the Scheffe comparisons for the

---

[s] For this and each of the subsequent tests of Scheffe contrasts a single pooled error term was used. The pooled error term was obtained by combining the residual sums of squares from the main ANOVA and their respective degrees of freedom (see Winer, 1971, Pp. 745-747). Since the error terms can be pooled only when there is no evidence of heterogeneity among them, F tests of homogeneity of variance were done in each case to decide whether or not all or at least two of the residual terms can be pooled together.

percentage of HR acceleration scores[6] show that ambiguity makes the perception of a sentence more difficult only when both the meanings have relatively equal strength and not when the sentence is heavily biased toward one of the meanings.

HR Deceleration. The mean scores for the percentage of HR deceleration were 3.802 for all the unambiguous sentences (control 1 and 2 conditions put together), 5.581 for the high bias ambiguous sentences, and 5.999 for the low bias ambiguous sentences. Table 3 gives the summary of the analysis of variance for the percentage of deceleration scores. Significant ambiguity main effect was obtained, $F(2,54) = 17.65$, $p<.01$. A three-factor interaction among Ambiguity, Bias, and Sentence-Cluster was also significant. However, as pointed out earlier, test of this interaction is based only on partial information and therefore, no attempt will be made to interpret this effect, which could be either due to the interaction of specific sentences with the

---

[6] In a preliminary report of the results (Mohanty, 1977, Note 6) the data were subjected to a 3(Lists) X 12(Trials) repeated measures analysis of variance with subjects nested within Lists. The Ambiguity and Bias main effects and the Ambiguity X Bias interaction effects were tested by a series of Scheffe planned orthogonal contrasts using the error term in the main ANOVA. Comparable significance of the F ratios were obtained and the main conclusions still remained the same. However, this method of analysis was abandoned for two reasons. First, the Scheffe test is mostly used for comparison among the treatment means following a significant overall F in the main ANOVA and not for the test of treatment effect itself. Second, as Winer (1971, p. 175) pointed out, when a large number of Scheffe comparisons are made some of them may be significant just due to the chances of Type I error.

Table 3
ANOVA summary table
for
the Percentage of HR Deceleration Scores

Source	df	MS	F
Between People	29		
Groups (G)	2	12.089	1.03
People within Gr. (P:G)	27	11.789	
Within People	150		
Ambiguity (A)	2	78.995	17.65**
Sentence-Cluster (C)	2	4.199	0.94
(AC)'	2	2.689	0.60
Residual (1)	54	4.475	
Bias (B)	1	6.776	1.94
B X G	2	0.106	0.03
Residual (2)	27	3.499	
B X C	2	5.970	1.87
A X B	2	0.131	0.04
(AC)' X B	2	24.138	7.58**
Residual (3)	54	3.186	

Note: All three Residual sums of squares were pooled and so were the respective degrees of freedom to obtain a Pooled MS error which was used for the Scheffe tests. Pooled MS error = 3.764, df = 135.
**p < .01

ambiguity and bias conditions or due to the arrangement of sentence-clusters in the specific Latin square used in the analysis. The ambiguity main effects were further analysed by Scheffe tests of planned contrasts. The mean of the low bias ambiguous sentence-clusters was significantly greater than the mean of the corresponding unambiguous sentences, $F(1,135) = 21.467$, $p<.01$. In the high bias condition the mean of the ambiguous sentence-clusters was significantly greater than the unambiguous controls, $F(1,135) = 20.515$, $p<.01$. Thus, for the percentage of HR deceleration measure, effect of sentence ambiguity seems to be significant in both the bias conditions. This is contrary to Hypothesis 1.2 which predicted a significant ambiguity effect in low bias condition but not in the high bias condition. Since the two bias conditions did not differ high- and low-bias of ambiguous sentences was not a significant variable for HR deceleration.

Reaction Time

The reaction time data were analysed for 27 subjects; two subjects were dropped because of failure to meet the response criteria which were, i) less than three errors and ii) less than two failures to respond within four seconds. One subject was eliminated randomly to make the group sizes equal. The mean RTs for the high- and low-bias ambiguous sentences and the unambiguous sentences were 1637.7, 1592.5, and 1441.7 milliseconds, respectively. Subjects' reaction

times for each type of sentence were further broken down according to the probe word types. The mean and standard deviation of the RTs for different probe word categories are given in Table 4. As pointed out earlier, this technique of giving probe words of different types of relevance was taken from an earlier study by Shanon (1974). In his study, subjects were given simple sentences in which the main noun was either a homophone or a regular (unambiguous) word. The sentences with homophones, however, provided a clear disambiguating context e.g. the homophone organ, which could mean either part of a body or an instrument, was given in the sentence The organ is healthy. The ambiguous sentences were followed by probe words, i) related to the contextual meaning of the homophones (Homophone - yes, e.g. The organ is healthy. -- Body), ii) related to the context - irrelevant meaning (Half-relevant, e.g. The pitcher is full -- Baseball), and iii) probe words completely irrelevant (Homophone - no, e.g. The table is complicated. -- Health). The unambiguous sentences were followed by either related or unrelated probe words. In the present study the same types of probe words as in Shanon's study were given[7] besides another category in which the probe words were related to both the meanings of the ambiguous sentences (Y:b). However, in this study, both high- and low-bias ambiguous sentences

---

[7] Shanon's (1974) Homophone - yes and Half-relevant categories are same as Yes: dominant (Y:d) and Yes: non-dominant (Y:n-d) types respectively, in the present study.

Table 4

Reaction Time to Probe Words
(Obtained and Predicted Ranks)

Sentence Type	Probe[1] Type	RT[2] (millisec) (Mean & SD)	Rank orders Obtained	Predicted[3] 1	2	3
Unambiguous	Y:un (108)	1372.6 (354.9)	3	3	3	3
	N:un (108)	1510.7 (351.5)	4	7	6	6
High Bias Ambiguous	Y:b (9)	1347.1 (245.7)	2	3	3	3
	Y:d (9)	1586.0 (355.3)	6	3	3	3
	Y:n-d (9)	2075.9 (263.0)	10	9.5	7.5	9
	N:am (27)	1605.7 (327.7)	7	7	9.5	10
Low Bias Ambiguous	Y:b (9)	1573.7 (276.7)	5	3	3	3
	Y:d (9)	1261.7 (355.8)	1	3	3	3
	Y:n-d (9)	1844.4 (304.1)	9	9.5	7.5	7
	N:am (27)	1626.4 (440.6)	8	7	9.5	8

Note 1: Numbers in parentheses represent the number of responses from which the means were computed.

Note 2: SDs are given in parentheses.

Note 3: Columns 1, 2, and 3 represent predictions of the unitary perception, the perceptual closure, and the perceptual suppression models, respectively.

were taken wheras in Shanon's study the sentences were clearly of high-bias category. Although the study did not measure the bias of the sentences, the context of the homophones create a dominant bias in favor of one meaning.

Shanon's (1974) findings were inconclusive at least partly because in his study bias levels of the sentences were not taken into consideration. In the present study bias of the ambiguous sentences was varied and the models of ambiguous sentence perception were used to predict the pattern of RTs to the probe words of different categories. The RT data were analysed to find out how well they fit the predictions of the three models. Ten categories of probe words were used in the study. Two of them were related and unrelated probe words for the unambiguous sentences (Y:un and N:un, respectively). Four others, viz., related to both the meanings (Y:b), related to the dominant meaning (Y:d), related to non-dominant meaning (Y:n-d), and unrelated (N:am) types, were repeated for high- and low-bias ambiguous sentence conditions. The predicted relationship among the mean RTs to these ten categories of probe words was expressed as a rank-order equation for each of the three models. Two assumptions were made. It was assumed that when a probe word is compared with any single meaning of a sentence, other conditions remaining the same, 'yes' responses are elicited earlier than 'no' responses. For unambiguous sentences, for example, 'no' response to an unrelated probe word takes longer than a 'yes' response to a

related one. This assumption is supported by some empirical evidence (see Shanon, 1974). Further, when a model did not specifically predict any relationship between two probe-types a null relationship of no difference was assumed. The rank-order equations for each of the models are given below.

The unitary perception model: According to the predictions of this model, as discussed earlier, RT to probe words which are related to the non-dominant meaning of the ambiguous sentences should be the longest and bias condition should have no effect. So, the rank-order relationship among the ten types of probe words should be:

(Y:un=Y:b(H)=Y:d(H)=Y:b(L)=Y:d(L))<(N:un=N:am(H)=N:am(L))<
(Y:n-d(H)=Y:n-d(L))....Eq(1)*

In other words, the unitary perception model would predict the following relationship for the RT to probe words of different types.

[RT to probe words related to unambiguous sentences; and related to the dominant meaning or to both meanings of ambiguous sentences of both high- and low-bias conditions]

should be less than

[RT to probe words unrelated to any meaning of ambiguous sentences of both the bias conditions and to unambiguous sentences]

should be less than

[RT to probe words related to the non-dominant meaning of ambiguous sentences of both the bias conditions]

---

* H and L in parentheses refer to high- and low-bias conditions respectively.

The perceptual closure model: According to this model the probe words unrelated to the meaning(s) of the ambiguous sentences should have longest RTs because they have to be compared with both meanings before a 'no' response is given. Further, bias condition should have no effect on RTs. The predicted relationships can be expressed thus:

$$(Y{:}un = Y{:}b(H) = Y{:}d(H) = Y{:}b(L) = Y{:}d(L)) < N{:}un < (Y{:}n\text{-}d(H) = Y{:}n\text{-}d(L)) < (N{:}am(H) = N{:}am(L)) \quad \ldots . \text{Eq}(2)$$

In other words, the perceptual closure model would predict the following:

[RT to probe words related to unambiguous sentences, and related to the dominant meaning or to both meanings of ambiguous sentences of high- and low-bias conditions]

should be less than

[RT to probe words not related to unambiguous sentences]

should be less than

[RT to probe words related to the non-dominant meaning of ambiguous sentences of both the bias conditions]

should be less than

[RT to probe words unrelated to any meaning of ambiguous sentences of both the bias conditions]

The perceptual suppression model: RT to probe words related to the non-dominant meaning and unrelated probe words, according to this model, should be longer in the high-bias ambiguous sentence condition than the RT to similar probe word categories in the low-bias condition which, in turn, should be longer than the RT to the unrelated probe words for unambiguous sentences. The other relationships should remain the same. Thus,

(Y:un=Y:b(H)=Y:d(H)=Y:b(L)=Y:d(L))<N:un<(Y:n-d(L))<N:am(L)<
Y:n-d(H)<N:am(H)....Eq(3)

The relationship predicted by the perceptual closure model can simply be expressed as:

[RT to probe words related to unambiguous sentences and related to the dominant meaning or to both meanings of ambiguous sentences of high- and low-bias conditions]

should be less than

[RT to probe words not related to unambiguous sentences]

should be less than

[RT to probe words related to the non-dominant meaning of low-bias ambiguous sentences]

should be less than

[RT to probe words unrelated to any meaning of low-bias ambiguous sentences]

should be less than

[RT to probe words related to the non-dominant meaning of high-bias ambiguous sentences]

should be less than

[RT to probe words unrelated to any meaning of high-bias ambiguous sentences]

The three equations were converted into predicted rank order scores which are given in Table 4 along with the actual rank order for the mean RTs obtained in the study. Rank scores increase with the RT and as usual, in case of a tie, the tied probe categories were given the average of the ranks they would have received if there were no ties.

The relationship between the pattern of ranks predicted by each model and the actual ranks obtained from the data should give an indication of how well the data fits each

model. The Kendall rank correlation coefficients: T(tau) corrected for rank ties (Siegel, 1956) were computed. The correlation coefficients (T) between the obtained ranks and ranks predicted by the unitary perception, the perceptual closure, and the perceptual suppression models were .723 (p <.01), .545 (p<.05) and .579 (p<.05) respectively. The unitary perception model was the best predictor of the obtained ranks. However, this does not permit a clear choice because the correlation between predictions of the other models with the data also reached the level of significance. This is not surprising in view of the fact that the first five ranks predicted by all three models were identical. The Kendall coefficient of concordance (W) for all four sets of rankings was significant, W = .876, df = 9, p<.001. It shows that the predictions of the three models were highly related among themselves and also with the obtained set of ranks. In the next step of analysis, therefore, the probe word categories corresponding to the first five ranks predicted identically by the three models were dropped and the Kendal correlation coefficients were computed for the remaining five categories (viz., N:un, N:a(H), N:a(L), Y:n-d(H), Y:n-d(L)). The obtained set of ranks still had a significant correlation with the ranks predicted by the unitary perception model, T = .78, p<.05, whereas the correlation coefficients with the ranks predicted by the perceptual closure and the perceptual suppression models dropped to 0 and .2 (p>.05) respectively. It seems the unitary perception

model fits the data better than the other models.

An analysis of variance in the main Latin square design lends further support to the unitary perception model. The analysis was carried out with the realisation that the probe types were not balanced within the cluster of sentences although they were balanced for the other dimensions of the Latin square. In other words, the cluster effect for the RT data is confounded with the effects of probe types, but the tests of bias and ambiguity effects could still be made in the analysis of variance summarized in Table 5. The main effect of Ambiguity was significant, $F(2,48) = 21.11$, $p<.01$, whereas the effect of Bias was not significant ($F<1$). This confirms the unitary perception hypothesis which predicted effect of ambiguity on RT to probe words particularly due to the probe words of the Y:n-d category, but no effect of bias. The main effect of sentence-cluster (C) was significant, $F(2,48) = 21.51$, $p<.01$; so was the partial Ambiguity x Sentence-cluster x Bias interaction effect, $F(2,48) = 5.94$, $p<.01$. Interestingly enough the two most difficult probe categories with the probe words related to the non-dominant meaning of ambiguous sentences (Y:n-d) occurred in sentence-cluster 1 (C1), whereas clusters 2 and 3 were balanced for the other probe-categories. The mean RTs for the three clusters (1617.1, 1447.9, and 1433.4 milliseconds for clusters 1, 2, and 3, respectively) clearly reflect this difference. On the whole, the results of the analysis of variance as well as the comparisons of RTs for

Table 5
ANOVA summary table
for
the Reaction Time Scores (in millisecs.)

Source	df	MS	F
Between People	26		
Groups (G)	2	807808.0	2.06
People within Gr. (P:G)	24	391338.6	
Within People	135		
Ambiguity (A)	2	552448.0	21.11**
Sentence-Cluster (C)	2	563026.5	21.51**
(AC)[1]	2	33837.5	1.29
Residual (1)	48	26176.0	
Bias (B)	1	1024.0	0.05
B X G	2	29184.0	1.55
Residual (2)	24	18773.3	
B X G	2	5031.0	0.14
A X B	2	67328.0	1.89
(AC)[1] X B	2	211417.0	5.94**
Residual (3)	48	35594.7	

**$p < .01$

various probe types support the hypotheses derived from the unitary perception model. It appears, in a task like the one given in this study subjects follow a unitary perception process. At least, some time after the initial processing of an ambiguous sentence the comparison of its meaning to a given probe word is done as if the sentence has one contextual meaning. The other meaning of the sentence is considered only when the probe word is related to the less dominant meaning of the ambiguous sentence thus externally changing the initial context of the sentence to a certain degree. In such a case, the original bias of the meanings has little to do with the time taken in the process of comparison. The question whether the sentences are processed unitarily right from the beginning or whether people use such a task-related strategy only when they have to respond in a probe-word type of situation cannot, however, be answered from an examination of the RT data alone particularly since in the present study the task was given after a considerable length of time. The heart rate and the reaction time data will be considered together in the following section in an attempt to answer this question.

The mean RTs for each type of probe words in Shanon's (1974) study were compared with the corresponding probe-types for unambiguous and high bias ambiguous sentences. The rank order of RTs in the present study was the same as in Shanon's (1974) study. In both studies RT to the probe words related to the less dominant meaning of (high bias)

ambiguous sentences was the longest. The RT to the probe words unrelated to the (high bias) ambiguous sentences was the next, followed by the RT to the probe words related to the dominant meaning of the (high bias) ambiguous sentences. The last two in the rank order were the RTs to the probe words unrelated and related to the meaning of the unambiguous sentences. The time intervals between the offset of the sentences and the onset of the probe words in Shanon's (1974) study were 1500 milliseconds in Experiment I and 500 milliseconds in Experiment II. Shanon did not find any effect of the time gap; RTs in two experiments were almost identical. It is interesting to note that the results of the present study generalize Shanon's findings to an interval as long as 21 secs.

Discussion

In summary, the HR acceleration data support the hypothesized dual process model -- exhaustive computation for the low bias ambiguous sentences and unitary perception for the high bias ambiguous sentences. The Ambiguity x Bias interaction effect was significant. Looking into the specific Scheffe comparisons, the ambiguity effect was significant in the low bias condition but not in the high bias condition. Studies on Lacey's intake-rejection hypothesis, reviewed earlier, very clearly suggest that cardiac acceleration is quite a reliable indicator of internal cognitive activity. Further studies by Kahneman,

Tursky, Shapiro, and Crider (1969), Tursky et al. (1970) and others (e.g., Jennings, 1971) have shown that the complexity of the cognitive activity is positively related to the degree of acceleration. In the present study the subjects were asked to understand the meaning of the sentences and were also told that the sentences were to be followed by a task in which they have to indicate if the sentence is related to a given probe word. Considering that the error was only 1.23% of the total responses it can be assumed that the subjects did make an effort to understand the sentences presented to them. Acceleration of heart rate clearly indicates the cognitive activity associated with trying to process the information contained in the sentences and to perceive their meaning. Further, significant Ambiguity x Bias interaction effect for percentage of HR acceleration provides evidence for exhaustive computation of ambiguous sentences of low-bias level and unitary perception of high-bias ambiguous sentences. It seems, the subjects perceive the high bias ambiguous sentences as they perceive any unambiguous sentence; only one meaning is processed and the sentence is most likely not seen as ambiguous. Both the meanings of low-bias ambiguous sentences, on the other hand, are computed and the sentence is most likely perceived as ambiguous.

According to Lacey's intake-rejection hypothesis an initial deceleration of heart rate could have been expected during the information 'intake' phase in which subjects

attend to the external stimulation. However, as Kahneman et al. (1969) have found, an accelerative pattern can be dominant particularly when subjects are given instruction and also, as in the present study, knowledge of the task prior to the presentation of the stimulus.

The analysis of the percentage of heart rate deceleration shows that the effect of ambiguity was significant regardless of the bias level of the ambiguous sentences. As pointed out earlier, when a subject knows that a stimulus is to be followed by a task such as reacting to probe words in this study, his HR accelerates during processing of the stimulus and decelerates prior to task performance. Cardiac deceleration in such cases indicates a preparation to respond or a cardiac orienting effect (Coles, 1974; Coles & Duncan-Johnson, 1975). In other words, it indicates subject's preparation to attend to an external task-related event. A greater complexity of the initial stimulus, or a greater uncertainty associated with its processing, as in the case of Das and Bower's (1973) 0.70:0.30 probability condition, not only makes the subject think harder to understand the stimulus, it also makes him pay greater attention to the approaching task; congruent with Lacey's hypothesis this attention to an external event accounts for HR deceleration observed in this study. The results show that sentence ambiguity leads to a greater attention and response-readiness to the probe word task. This finding is interesting, particularly in view of the

fact that the acceleration data shows that only one meaning of high bias ambiguous sentences may have been processed. One can conclude that although high bias ambiguous sentences are processed unitarily there is still some degree of uncertainty associated with its comprehension. In other words, even when subjects perceive only one meaning of high-bias ambiguous sentences and process it in the same manner as any unambiguous sentence, they are not so sure of its meaning.

Congruence between HR and RT. The heart rate data, thus, seem to be compatible with the hypothesis that both the meanings of low bias ambiguous sentences are processed thus making their perception more complex whereas in the case of the high bias ambiguous sentences only one meaning is processed. The reaction time data, on the other hand, seems to give overall support for the unitary perception model. One indication of unitary perception is that RT to the probe words which were related to the less dominant meaning of ambiguous sentences (Y:n-d) (e.g. The lawyer insisted that the charge was unjust -- COSTLY) is longer than the RT to the probe words unrelated to the ambiguous sentences (N:am). Extra time is apparently taken up in reprocessing of the sentence because the less dominant meaning is called for by the context which the Y:n-d type of probe word provides. In the present study the RT to the Y:n-d type of probe words were longer than the N:am types in both the bias conditions. This difference would support a unitary perception model

even for the low bias ambiguous sentences. However, the difference between the mean RTs for the Y:n-d and N:am types of probe words is 218.0 msec. in the low bias condition and 470.2 msec. in the high bias condition. In other words, the extra time taken to perceive the less dominant meaning of the ambiguous sentences is more in the high bias condition than in the low bias condition. This relationship is exactly what the perceptual suppression model would predict because according to this model the dominant meaning has to be suppressed before the other meaning can be perceived. Further, the time taken to suppress the dominant meaning varies directly with its bias. Thus, the possibility of a perceptual suppression process cannot be ruled out.

These apparently conflicting results can be explained by taking the time interval between the stimulus sentences and the probe words into consideration. In the event of an exhaustive computation where both the meanings of ambiguous sentences are non-selectively accessed to begin with, there follows as MacKay (1970) has argued an interaction between the two meanings involving a process of suppression. However the perceptual suppression process cannot go on indefinitely. At some point, choice of a single meaning has to be made either by suppressing, more or less permanently, one of the meanings or, as in the case of appreciation of puns, integrating the meanings into one another. In any event, interaction among the meanings finally leads to what can be called a perceptual closure. But such perceptual

closure does not necessarily have to occur immediately at the end of a clause boundary (cf. Bever et al. 1973); it is a process which occurs over a period of time the length of which depends on a number of factors including relative bias of the meanings. In other words, exhaustive computation of the meanings of ambiguous sentences leads to a selective unitary process sooner or later depending upon how long it takes to arrive at a perceptual closure. In the case of low bias ambiguous sentences, perceptual closure follows a relatively long process of perceptual suppression because it is harder to drop a meaning which is nearly as likely as the other. At the same time, the longer it takes to suppress a meaning the easier it is to retrieve that meaning from memory should it be necessary to do so. This might explain why the RT to Y:n-d type of probe words is less in the low bias conditions compared to the high bias condition.

In conclusion, it is observed that the high bias ambiguous sentences are perceived unitarily. The less likely meaning of such sentences is not accessed until it is justified by a subsequent context like the one provided by the probe words related to less dominant meanings. In such a case the sentence is reprocessed and the other meaning is also perceived. The low bias ambiguous sentences, on the other hand, appear to be processed exhaustively and both the meanings, accessed in a non-selective manner, interact with each other. The results of the RT task was explained by assuming that this interaction most likely involves a

perceptual suppression process which finally results in a more or less permanent suppression of one of the meanings or in an integration of one meaning into another. At this point, the perception of the ambiguous sentences can be said to have become unitary. However, should an occurrence of a context beyond this point make it more likely, the suppressed meaning has to be retrieved. The longer it takes to suppress a meaning the easier it is to retrieve when the context is changed.

CHAPTER III

EXPERIMENT 2

Rationale and Hypotheses

Ambiguous sentences have been widely classified into three kinds: those with ambiguities at lexical, surface structure, or deep structure levels. Is the perception of one type more complex than the other? No conclusive answer can be obtained by reviewing the existing studies. Bever et al. (1973) argued that the degree of complexity of different types of ambiguous sentences depends on the task characteristics -- on the point of initiation of the task performance relative to the processing of the sentence and on the nature of the response requirements. However, as pointed out earlier, it is both logical and possible to determine the relative degree of perceptual complexity of the three types of ambiguous sentences independently of any task performance by the use of electrophysiological changes such as HR, EEG etc. The first experiment provided a methodology and demonstrated the use of HR measures, in comparison of perceptual complexity of sentences by varying their degree of ambiguity. The results of the Experiment 1 also indicated that the bias of the meanings must be controlled in any attempt to compare the perceptual complexity of ambiguous sentences of different types. It is

possible that the conflicting findings in the literature regarding the perceptual complexity of the lexical, surface structure, and deep structure types of ambiguous sentences can be attributed partly to the lack of control for the bias level of these sentences and also partly to the use of different experimental tasks. The purpose of this experiment, therefore, was to compare the effects of lexical, surface structure and deep structure types of ambiguity on the perceptual complexity of sentences all of which are in the low bias range.

As in the previous experiment, the low bias ambiguous sentences were those for which 50 - 70% of the subjects paraphrased one of the meanings the rest paraphrasing the other. Percentage of HR acceleration and deceleration were used as directly related indicies of difficulty in processing while comparing the different types of sentences. The results of Experiment 1 showed that low bias ambiguous sentences of the lexical type are most likely perceived exhaustively, that is, both the meanings of such sentences are non-selectively accessed making their perception more complex than the unambiguous sentences. For the present experiment, also, a similar effect was expected. In regard to the percentage of HR acceleration and deceleration scores the following were, therefore, hypothesised:

> Hypothesis 1.1: HR acceleration following the presentation of low bias ambiguous sentences of lexical, surface structure, and deep structure types is significantly greater than that following the presentation of unambiguous sentences.

Hypothesis 2.1: HR accelerations due to the effects of lexical, surface structure, and deep structure types of ambiguity are significantly different from each other.

Hypothesis 1.2: HR deceleration following the presentation of low bias ambiguous sentences of lexical, surface structure, and deep structure types is significantly greater than that following the presentation of unambiguous sentences.

Hypothesis 2.2: HR deceleration due to the effects of lexical, surface structure, and deep structure types of ambiguity are significantly different from each other.

In summary, significant Ambiguity X Sentence-Type interaction and Ambiguity main effects were expected. In the event of significant Ambiguity X Sentence-Type interaction paired comparisons for ambiguity effect in different sentence-type conditions were also planned without any a priori hypothesis regarding the direction of the differences.

A reaction time task similar to the one in the first experiment was also used. But, unlike the first experiment, only two types of probe words, viz, related and unrelated types, were given. The results of Experiment 1 showed a significant effect of ambiguity on the RT to probe words. RTs to related and unrelated probe words in the low bias condition were greater than the RTs to similar types of probe words for the unambiguous sentences although the general trend of RT to probe words of different types suggested that at some point after the initial exhaustive computation there is perceptual closure with the selection of a single meaning or integration of the meanings into a unitary perception. Thus, the following were hypothesized:

Hypothesis 3: RT to probe words following low bias ambiguous sentences of lexical, surface structure, and deep structure types are significantly different from the RT to probe words following the unambiguous sentences.

Hypothesis 4: The effects of ambiguity on RT to probe words in lexical, surface structure, and deep structure types of ambiguous sentence conditions are significantly different from each other.

Again, in regard to the RT task, significant Ambiguity X Sentence-Type interaction, and Ambiguity main effects were expected. Comparisons were planned to find out the specific differences among the three sentence-type conditions.

Method

Stimulus sentences and probe words

For this experiment 18 low bias ambiguous sentences -- six each from lexical, surface structure, and deep structure types -- and their respective pair of controls were used. The criteria for selection of these sentences and the norming procedure were described in the previous chapter.

Only related and unrelated types of probe words were used in the unambiguous sentence condition (Y:un, N:un) and in each of the three types of ambiguous sentence conditions (Y:am, N:am). Within each condition the probe words were balanced for related and unrelated types. Probe words of the Y:am type were related to both the meanings of ambiguous sentences except for two sentences in which case they were related only to the dominant meaning.

Design of the experiment

The design of the experiment was the same as that of the Experiment 1 with only the bias conditions replaced by the sentence-type conditions. The ambiguous sentences were divided into three lists -- each with clusters of two lexical, two surface structure, and two deep structure types of ambiguous sentences. The pair of unambiguous control sentences corresponding to the ambiguous sentences were randomly assigned to two lists other than the one in which the respective ambiguous sentence appeared. Thus, each list had 18 sentences six of which were ambiguous. Within each sentence-type condition a list had a cluster of two ambiguous sentences, a cluster of two unambiguous control sentences corresponding to the ambiguous sentences (of the same type) in the second list, and another cluster of two unambiguous controls corresponding to the ambiguous sentences in the third list. As in Experiment 1, the related-unrelated probe words (i.e. the yes-no response types) were balanced within each list for ambiguous sentences of different types and for unambiguous sentences. The probe words for ambiguous sentences were also used for one of the corresponding pair of controls. Winer's Plan 12 repeated measures Latin square design, similar to Experiment 1, was followed with Ambiguous Sentence Type (T), Ambiguity (A), and Sentence-cluster (C) factors repeated and subjects (P) nested within the lists.

Arrangement of intra-trial events and the intervals were the same as in Experiment 1. An experimental session consisted of 18 trials one for every stimulus sentence in the list to which the subjects were randomly assigned.

Subjects

The subjects were 30 male undergraduate students from the University of Alberta. None of the subjects had participated in Experiment 1. All of them were native speakers of English and were unilinguals. The average age of the subjects was 21.57 years and the the range was 18-27 years. All the subjects were right handed except one who preferred use of the left hand. None of the subjects reported any sensory-motor impairment. Subjects were paid $2.50 each for participation in the experiment.

Apparatus

Experimental events and the recording of HR and RT were controlled by the same equipment and set up as in the first experiment.

Procedure

The experimental procedure was similar to Experiment 1. Since there were more trials in the present experiment the experimental session including a brief post-experimental interview took approximately 50 minutes per subject.

Results and Discussion

The records of subjects' heart rate were scored using the same procedure as in Experiment 1. The Heart Rate Blocking and Analysis Program was also used in computing the pre-stimulus HR, percentages of acceleration and deceleration, and second-by-second changes in the BPM scores. The average pre-stimulus HR for all the subjects was 79.28. There was no significant difference among the three groups in regard to the pre-stimulus HR ($F<1$). The average second-by-second BPM changes over the pre-stimulus HR for unambiguous, and lexical, surface structure, and deep structure types of ambiguous sentences are shown in Figure 2. HR changes in all the sentence conditions follow a similar accelerative and decelerative pattern. Amount of change is generally larger for the deep structure type of ambiguous sentences.

The percentage of acceleration and deceleration scores and the RT data were analysed in Groups x Ambiguity x Cluster x Sentence (Ambiguity) Type analyses of variance for the Latin square design. Winer's (1971, Pp. 745-748) two-stage procedure, described in Chapter II, was followed for these analyses.

HR Acceleration

The means of the percentage of HR acceleration were 7.321, 7.261 and 8.387 for the lexical, surface structure and deep structure types of ambiguous sentences,

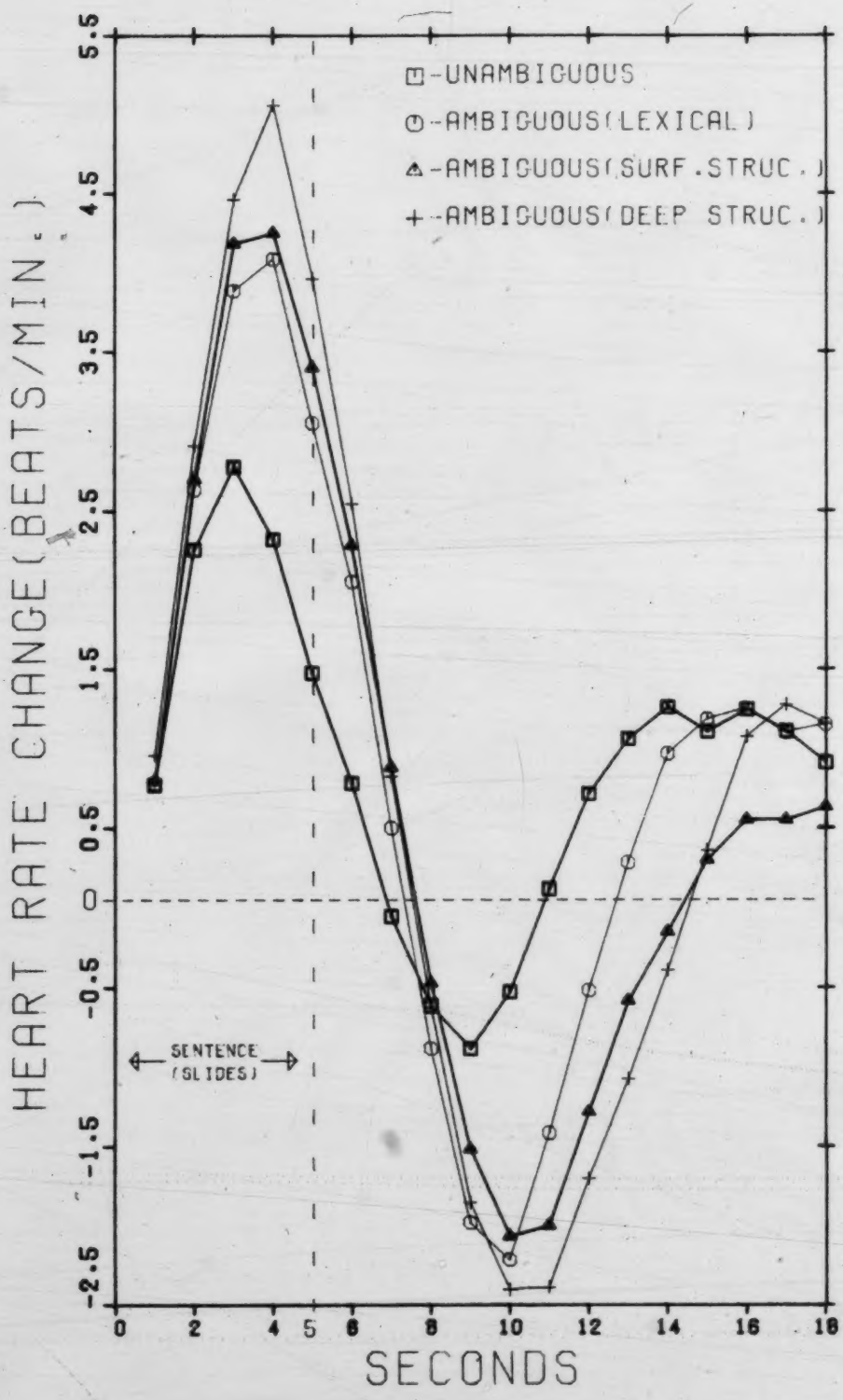

Figure 2. Mean Second-by-Second Changes in Heart Rate

respectively and 5.581 for unambiguous sentences. The summary of the analysis of variance for the percentage of HR acceleration are presented in Table 6. As predicted, Ambiguity x Sentence-Type interaction and Ambiguity main effects were both significant, $F(4,108)=4.96$, $p<.01$, and $F(2,54)=62.07$, $p<.01$ respectively. The interaction effect was further analysed in Scheffe tests of planned comparison. The effect of ambiguity, in terms of the difference between the ambiguous and the respective unambiguous control sentences, was significantly greater in deep structure ambiguity condition than in surface structure ambiguity condition ($F(1,216)=12.59$, $p<.01$) and in lexical ambiguity condition ($F(1,216)=7.11$, $p<.01$). The ambiguity effects in lexical and surface structure types of ambiguity conditions did not differ significantly ($F<1$). Scheffe tests for ambiguity main effects revealed significant ambiguity effects within lexical ($F(1,216)=36.28$, $p<.01$), surface structure ($F(1,216)=22.81$, $p<.01$), and deep structure ($F(1,216)=95.92$, $p<.01$) sentence conditions. Thus, both hypotheses 1 and 2 were supported by the results. The percentage of HR acceleration due to perceptual complexity of ambiguous sentences of deep structure type seem to be greater and also significantly different from those of surface structure and lexical types. The difference between lexical and surface structure ambiguity conditions was not significant. The percentage of HR acceleration data further indicated that ambiguity makes the perception of sentences more complex in

Table 6
ANOVA summary table
for
the percentage of HR Acceleration scores

Source	df	MS	F
Between People	29		
Groups (G)	2	20.082	1.36
People within Gr. (P:G)	27	14.768	
Within People	240		
Ambiguity (A)	2	129.303	62.07**
Sentence-Cluster (C)	2	14.446	6.94**
(AC)[1]	2	8.573	4.12*
Residual (1)	54	2.083	
Ambiguity-Type (T)	2	2.148	1.46
T X G	4	1.289	0.87
Residual (2)	54	1.474	
T X C	4	5.752	3.06*
A X T	4	9.321	4.96**
(AC)[1] X T	4	9.392	5.00**
Residual (3)	108	1.878	

Note: All the Residual sums of squares and their respective degrees of freedom were pooled to obtain the Pooled MS error which was used for Scheffe tests. Pooled MS error = 1.828, df = 216
*p < .05 **p<.01

each of the three ambiguity-type conditions.

Significant Ambiguity-Type x Sentence-cluster interaction effect (F (4,108)=3.06, $p<.05$) and sentence-cluster main effect (F(2,54)=6.94, $p<.01$) were obtained in the analysis of variance for percentage of HR acceleration scores. As pointed out in Chapter II, an advantage of this design is that the effect of differences among the specific sentences used in this study and their interaction with other variables can be separated from the rest of the main and interaction effects. As such, the main effect of ambiguity and its interaction with ambiguous sentence type are not confounded in this analysis with the sentence-cluster effects.[9] However, the significant effect of sentence-cluster and its interactions with other variables should be of concern because it indicates that besides the ambiguity of lexical, surface structure, and deep structure types of sentences other factors might also cause processing complexity for sentences like the ones used in this study. In the usual experimental design of comparing unambiguous

---

[9] When the percentage of HR acceleration data were analysed in a 3(Groups)x18(Trials) repeated measures design and Ambiguity main effect and Ambiguity x Sentence Type interaction effect were tested by Scheffe planned comparisons the decisions in regard to the hypotheses of the experiment remained unchanged. However, it is interesting that in spite of the obvious disadvantages of such analyses (see Chapter 2, Note 6) the probabilities associated with the significant F ratios for Ambiguity and Ambiguity x Sentence Type effects were smaller than those in the present analysis. This may be due to the fact that in former analysis the significant effects were confounded with Sentence-cluster effects.

sentences and ambiguous sentences of various types it is, therefore, possible to misinterpret an effect of sentence difference as ambiguity effect.

Interactions of Sentence-cluster with Ambiguity and Sentence-Type ((AC)¹T) and with Ambiguity ((AC)¹) were also significant. These effects, however, are based only on partial information available in this design and according to Winer (1971, p. 748), these sources of variation can be considered to be a function of the particular Latin square selected for use.

HR Deceleration

The mean percentage of HR deceleration scores were 3.992 for the unambiguous sentences and 5.210, 5.653, and 6.125, respectively, for lexical, surface structure and deep structure ambiguous sentences. The summary of analysis of variance is given in Table 7. The ambiguity main effect was significant, $F(2,54)=8.72$, $p<.01$. Further Scheffe tests revealed that the percentage of HR deceleration for lexically ambiguous sentences was not significantly different from those for the corresponding unambiguous controls, $F(1,216)=3.714$, $p>.05$. Within surface structure and deep structure conditions, however, the differences were significant, $F(1,216)=4.051$, $p<.05$, and $F(1,216)=11.426$, $p<.01$, respectively. The analysis of percentage of HR deceleration data, thus, confirms the findings of Experiment 1 that this measure may be related to subjects' attention

Table 7
ANOVA summary table
for
the percentage of HR Deceleration scores

Source	df	MS	F
Between People	29		
Groups (G)	2	36.850	2.79
People within Gr. (P:G)	27	13.230	
Within People	240		
Ambiguity (A)	2	90.326	8.72**
Sentence-Cluster (C)	2	18.772	1.81
(AC)[1]	2	4.775	0.46
Residual (1)	54	10.363	
Ambiguity-Type (T)	2	3.750	0.39
T X G	4	12.435	1.30
Residual (2)	54	9.547	
T X C	4	7.063	0.80
A X T	4	13.929	1.59
(AC)[1] X T	4	8.174	0.93
Residual (3)	108	8.785	

Note: All the Residual sums of squares and their respective degrees of freedom were pooled to obtain the Pooled MS error which was used for Scheffe tests. Pooled MS error= 9.369, df = 216.
**p < .01

and readiness to respond to the probe words in the reaction time task.

Reaction Time

The mean RTs were 1374.67 msecs. for unambiguous sentences and 1373.28, 1394.55, and 1437.98 msecs., respectively, for lexical, surface structure, and deep structure ambiguous sentences. The results of the analysis of variance, summarized in Table 8, showed that the effect of ambiguity is not significant ($F < 1$). So, hypothesis 3 was not supported by the results. However, significant Ambiguity x Sentence-Type interaction effect was obtained ($F(4,108)=4.41$, $p<.01$) in support of the hypothesis 4, showing that ambiguity effects in the three sentence type conditions were different from each other. The interaction effect was further examined by Scheffe tests of planned contrasts. The difference between the mean RT for the ambiguous and their corresponding unambiguous control sentence-clusters was significantly greater in deep-structure condition than in lexical condition ($F(1,216)=4.43$, $p<.05$). The other pairs of differences between deep and surface structure conditions ($F < 1$), and between surface structure and lexical conditions ($F(1,216)=1.32$, $p>.05$) were not significant. Within the sentence type conditions ambiguity effect was significant only for deep structure type of ambiguous sentences ($F(1,216)=4.13$, $p<.05$) but not for lexical and surface structure types ($F <1$ for both). The results show

Table 8
ANOVA summary table
for
the Reaction Time Scores (in millisecs.)

Source	df	MS	F
Between People	29		
Groups (G)	2	127488.00	0.36
People within Gr. (P:G)	27	349563.25	
Within People	240		
Ambiguity (A)	2	18688.00	0.53
Sentence-Cluster (C)	2	380384.63	10.86**
(AC)[1]	2	208671.38	5.96**
Residual (1)	54	35010.37	
Ambiguity-Type (T)	2	18304.00	0.42
T X G	4	53632.00	1.24
Residual (2)	54	43197.63	
T X C	4	410214.75	8.87**
A X T	4	103776.00	4.41**
(AC)[1] X T	4	251545.25	5.44**
Residual (3)	108	46248.29	

Note: All the Residual sums of squares and their respective degrees of freedom were pooled to obtain the Pooled MS error which was used for Scheffe tests. Pooled MS error= 42676.15, df = 216.
**p < .01

that the ambiguity of sentence does not affect the RT to probe words except for deep structure type of sentences. It seems, during the interval between the stimulus sentences and the probe words the subjects were able to resolve the lexical and surface structure types of ambiguity most likely, as Experiment 1 showed, following a process of perceptual suppression. Since only related (mostly to both the meanings) and unrelated types of probe words were given (as opposed to the probe words related to the less dominant meaning in Expt. 1) such resolution of ambiguity does not create any additional problem.

Significant Ambiguity-Type x Sentence-cluster interaction effect ($F(4,108)=8.87$, $p<.01$) and sentence cluster main effect ($F(2,54)=10.86$, $p<.01$) were obtained. As pointed out earlier, these effects may be due to the uniqueness of the sentences used in the study.

Discussion

The results of HR acceleration measure support the conclusion drawn from Experiment 1 that lexically ambiguous sentences of the low bias range are most likely processed exhaustively and also extend this conclusion to the low bias ambiguous sentences of surface and deep structure types. Further, the degree of complexity of deep structure type of ambiguous sentences seem to be greater than lexical and surface structure types. The perceptual complexity due to

lexical and surface structural ambiguities do not differ significantly. These results are consistent with the findings of Bever et al. (1973, Expt. II). In their study subjects were asked to complete sentence fragments; some of the fragments were incomplete clauses (e.g. After taking the right turn at the ....) and the others were complete clauses (e.g. After taking the right turn at the intersection ....). The underlying structure ambiguity increased the RT in the incomplete clause condition. Although the measures of perceptual complexity in the present study are independent of any overt task performance, similar results were obtained.

The significant effect of ambiguity for the percentage of HR acceleration and deceleration measures supports the hypothesis of exhaustive computation for the low bias ambiguous sentences of the three types. Ambiguity effect, however, was not significant for the RT to the probe words. Analysis of the significant Ambiguity x Sentence-Type interaction effect indicated that within the Sentence-Type conditions mean RT to deep structure types of ambiguous sentences was significantly greater than lexical type. The results for the RT task, thus, suggest a unitary perception process for the lexical and surface structure types of ambiguous sentences, and an exhaustive computation process for deep structure type of ambiguous sentences. This apparent conflict between the results for the HR measures and RT task can be resolved, as pointed out earlier, by

assuming that, over a period of time, the perception of ambiguous sentences changes in a unitary direction either by a choice of one of the meanings or by a process of integration of one meaning into another. Further, it seems, a perceptual closure occurs at some point of processing of ambiguous sentences but it does not always occur immediately at the ambiguous clause boundary; most likely it follows an interaction among the meanings and may occur at different points depending upon the nature of the sentences. In this case, the closure seems to take longer for sentences with underlying structural ambiguity than for sentences with lexical or surface structural ambiguities.

In conclusion, the results of Experiment 2 lend further support to the hypothesis that low bias ambiguous sentences are perceived exhaustively making them more complex than unambiguous sentences. Underlying structural ambiguity seems to make the perception of sentences most difficult whereas surface structural and lexical ambiguities do not differ in this respect. Further, even when ambiguous sentences are perceived exhaustively there is a tendency toward a unitary perception which occurs at various points depending, among other things, on the type of ambiguous sentences.

CHAPTER IV

GENERAL DISCUSSION AND CONCLUSION

The purpose of the study was to find out the effects of bias and sentence type on perception of ambiguous sentences in view of different models for such perception. Changes in HR were used as indices of processing complexity of sentences. Effect of bias was shown to significantly change the nature of perception of lexically ambiguous sentences. Type of sentence ambiguity was also found to be a significant variable affecting the perceptual complexity of sentences. The probe word task given 21 seconds after the off set of the sentence stimuli indicated that when both meanings of ambiguous sentences are perceived there follows an interaction among the meanings leading to a resolution of ambiguity. These three aspects of the study will be discussed in this chapter. Some implications of the study will be shown and its major conclusions will be summarized.

Perception of Ambiguous Sentences and the Language User's Knowledge of the World

Results of the first experiment support the hypothesised effect of bias on perception of ambiguous sentences. When an ambiguous sentence is considerably biased toward one interpretation over the other only one meaning is perceived as suggested by the unitary perception model. If

the sentence is relatively unbiased toward either interpretation, its meanings are exhaustively computed making its processing more difficult than unambiguous sentences. Results of the second experiment support the exhaustive computation model for the low bias ambiguous sentences.

The lexically ambiguous sentences used in the study were defined as those in which one of the words has two distinct meanings. The sentences in Experiment 1 were thus ambiguous from a linguistic point of view. The bias of these sentences were varied so that, in the context of the given sentences, the meanings were more or less likely. In the high bias condition probability of more likely meanings of the sentences was higher than 80% and in the low bias condition it was less than 70%. The results show that in the high bias condition perception of ambiguous sentences is no more complex than unambiguous control sentences; in both cases only one meaning is processed. What makes the perception of high bias ambiguous sentences less complex than low bias ambiguous sentences? The answer obviously does not lie in the linguistic properties of the sentences. The perceiver of an utterance, it seems, must make a judgment of the likelihood of occurrence of a meaning based on his knowledge of the world. Perception of ambiguous sentences is a cognitive phenomenon. Although the scope of a formal ambiguity may originate in the linguistic nature or syntactic properties of a sentence, the perceiver of such a

sentence will have to decide, on the basis of his world view, which events, objects or relations among them the speaker must have referred to. Consider the following sentences:

(1) There was an apple in the box and he ate it.
(2) There was an apple in the box and he opened it.
(3) There was an envelope in the box and he opened it.

According to the linguistic rules of pronominalization it in all of the sentences above may refer to either of the two nouns. Strictly speaking, therefore, all the sentences can be considered linguistically ambiguous. However, hardly any one would find (1) and (2) ambiguous because we know that ate it in (1) must refer to an apple and opened it in (2) to the box. But (3) is clearly ambiguous because opened it can refer to both an envelope and the box. An utterance may, at times, leave more than one alternative open but it becomes functionally ambiguous only when it does not leave the hearer with a clear choice among these alternatives on the basis of his knowledge of event probabilities. Support for the cognitive view of sentence comprehension is growing since Olson's (1970) cognitive theory of semantics in which he pointed out that "the semantic decision (such as the choice of words or sentences) is based on cognition, the knowledge of the intended referents, not on the rules internal to language (p. 259)." In other words, a speaker uses an utterance to differentiate a referent from a set of possible or perceived alternatives. Lenneberg (1975), in a posthumously published work, claimed that the linguistic

properties of utterances "interact inextricably with general problems of knowing (p. 23)." To take Lenneberg's examples, among the following phrases --

(4) the jailing of the thieves
(5) the bullying of the thieves
(6) the stealing of the thieves
(7) the stealing of the women
(8) the stealing of the infants

the most ambiguous are (5) and (7), whereas (4) and (8) can hardly be considered ambiguous. The degree of ambiguity in these phrases is based on our knowledge of the world and not on any absolute linguistic criteria. In fact, the 'unambiguous' phrases in the examples above can become ambiguous given a different context in which the judgment of the probabilities are altered. Thus, perception of ambiguity depends on the perception of available alternatives as much as it does on the linguistic nature of the utterance. Lenneberg (1975) further went on to say that the use of language involves a differentiation of the cognitive information about the world. An utterance helps the listener to perceive the differentiated meaning or reference intended by the speaker. However, when in some cases due to the nature of the total context in which an utterance appears, or even due to a discrepancy between the speaker's and the hearer's cognition of the available alternatives, the hearer fails to make a clear choice among the meanings available from the utterance. In such cases, he perceives more than one meaning and the utterance is functionally ambiguous. However, the fact that some other utterances, like the high

bias ambiguous sentences in this study can be linguistically analysed into two or more different propositions does not create any ambiguity for the hearer or the reader as long as in his cognitive process the reference made by these utterances is clearly differentiated. A listener's cognitive views of the alternatives may have a blinding effect on his perception of an utterance; he may perceive one meaning and ignore another potential meaning. This phenomenon comes close to Lashley's (1951) idea of 'priming' of an association and to the Wurzburg school's concept of 'determining tendency', which sets the perceiver to perceive only one of the available alternatives. Sometimes such perception may occur in spite of the linguistic structure if the event probabilities are predominantly in favor of a particular perceptual set. Clark and Clark (1977) call this the 'reality principle' of sentence comprehension. We tend to make a linguistic input match our existing cognition of the world as much as possible in deciding what the speaker must have had in his mind. Fillenbaum's (1971, 1974 a, b) works on 'pragmatic normalisation' illustrates this phenomenon. In his studies sentences like:

(9) John dressed and had a bath
(10) John finished and wrote the article on the week end.

were paraphrased inaccurately because in most cases people tended to 'normalise' the utterance to fit their view of how things work in the world in which people normally dress

after a bath and write something before finishing it.[10] Thus, in some cases, hearers or readers perceive a meaning that is normally more likely, in some others, the nature of the context, or rather the knowledge of such context, forces more than one meaning as possible alternatives and the hearers or readers perceive all the meanings. It is only in the latter case where a sentence becomes truly ambiguous. In summary, the following words from Olson (1970) clearly states the cognitive view of sentence ambiguity:

> (The) sentence specifies a perceptual context which then has the effect of eliminating one of the alternatives...., thereby disambiguating the sentence. If this is true, it follows that ambiguity is a function of the perceived alternatives to the intended referent, not of the rules of language.... an ambiguous sentence is one that, within the alternatives established by the intent of the speaker, leaves more than one alternative available, that is, fails to specify the intended referent (p. 260).

Perception of Ambiguous sentences and the Type of Ambiguity

Results of the second experiment extended the results for the low bias ambiguous sentences in Experiment 1 to all the three types of ambiguous sentences. The percentage of HR acceleration data showed the perception of low bias lexical, surface structure, and deep structure types of ambiguous sentences to be significantly more complex than their

---

10 It is interesting that when this was given to the typist she first typed the sentence (10) as John wrote and finished the article on the weekend.

corresponding unambiguous control sentences. Further, processing of deep structure types of ambiguous sentences was shown to be more complex than processing of surface structure and lexical types. The lexical and surface structure types however did not differ in this respect. The linguistic distinction between deep structure, surface structure and lexical ambiguities was taken as a conventional classification of sentence ambiguities and in view of the conflicting findings of previous studies, an attempt was made to compare the relative processing complexity of these types of ambiguous sentences with their bias level controlled at less than 70%. It must be pointed out that a demonstration of a difference between deep structure and surface structure types of ambiguities should not be construed as a proof of the so called 'psychological reality' of this distinction because such demonstration hardly shows anything about the actual processing strategy used by a language user. Further, the classificatory system itself is only a matter of definition, it does not follow directly from any particular version of the theory of transformational generative grammar. In fact, in Aspects of the theory of syntax (1965) Chomsky suggested that all ambiguities are necessarily resolved at the deep structure level. Since the conventional classificaiton of sentence ambiguity adapted in this study is not directly related to nor motivated by the logic of the deep- and surface-structure distinction it is hard to explain the obtained

difference in terms of any perceptual strategy that might be involved; at least, there is nothing in the results to suggest any. The perceptual theory of ambiguity, suggested by Bever et al. (1973) claims that different types of ambiguous sentences differ

> ....in the extent to which the perceptual mapping operations used to perceive one interpretation are identical with those used to perceive the other interpretation. In lexical ambiguities, the perceptual rules for the two meanings are virtually identical; in surface structure ambiguities, they may differ slightly; in underlying structure ambiguities they differ considerably (p. 282).

However, the so called perceptual mapping operations are themselves described in terms of transformational rules creating a circularity in the argument. Bever et al. (1973) also refer to 'independence of the meanings' as a factor affecting any task performance related to the perception of ambiguous sentences of different types, but they do not provide any system to measure the 'independence' of meanings of ambiguous sentences. At best, one can say, there is evidence for different levels of complexity of perception of the three types of ambiguous sentences but the specific nature of perceptual process involved is not yet known. The issue is further complicated by the fact that the conventional tripartite classification of sentence ambiguity may not be suitable nor exhaustive for a theory of ambiguous sentence perception.

Interaction among the Meanings following Exhaustive Computation

The results of the RT tasks in both the experiments show that when both the meanings of ambiguous sentences are computed, there is a tendency, following such perception, toward a unitary process. Mean RTs to different types of probe words could be best explained by the assumption that, once the two meanings are ccmputed, there is an interaction between them involving a mutual suppression. As a result of such interaction one of the meanings is either suppressed or, in some cases, integrated with the other meaning giving rise to a tentative acceptance and retention of the other. Time taken to suppress one meaning may depend on the difficulty of the cognitive decision and also may vary from one type of sentence ambiguity to another. The results of Experiment 2 suggest that it takes longer to resolve a deep structure ambiguity than the other types of ambiguity. It must be pointed out, however, that the interpretatin of the results of the RT task is limited by the fact that we do not know at what point of processing the comprehension of a sentence ends and its retention begins. This distinction is important in view of the long interval between sentences and probe words in the present study.

Implications

The findings of the present study have both theoretical and methodological implications. The study shows that

sentence ambiguity itself is as much a cognitive phenomenon as a linguistic one. In view of the fact that the distinction between a functional and linguistic definition of sentence ambiguity has created interpretation problems for earlier studies (see, for example, Garcia, 1976), the present findings are significant. From a methodological point of view, the results of Experiment 1 also demonstrate the necessity of considering and controlling for the [illegible] of the meanings in any study of ambiguity. The results of Experiment 2 show that processing of deep structure type of ambiguous sentences may involve a different perceptual mechanism or, at least, a different level of complexity from processing of lexical and surface structure types. The nature of the perceptual process involved in this difference, however, is not yet known.

Review of conventional procedures which have been used to study the complexity of sentence processing (see Olson & Clark, 1976) reveals a number of problems. The use of autonomic responses as indices of processing difficulty may prove to be a more useful technique than the conventional measures of processing complexity. As pointed out earlier, such measures are, in most cases, contaminated by interference of the task performance and task characteristics with the processing of the sentence itself and also by other factors like fading of memory, perceptual errors, and so on (see Olson & Clark, 1976, for a discussion). In the present method, the measure of

processing complexity of sentences is relatively independent of any such task related factors although a task orientation could not be completely eliminated.

Conclusion

In conclusion, the results of the study, supporting a dual process hypothesis in regard to perception of high- and low-bias ambiguous sentences and showing a difference between the three types of ambiguous sentences, have demonstrated a need to consider bias and sentence type as important parameters in developing a theory of ambiguous sentence perception. The study has also shown that the phenomenon of sentence ambiguity is primarily a cognitive one. However, the factors that affect the interplay between language users' views of the world or his cognitive processes and the perception of ambiguous sentences are not fully known. We do not know much, for example, about the decision making process following the perception of ambiguity. Further, the mechanisms involved in perception of different types of ambiguous sentences are yet to be explored. In other words, issues in ambiguity are far from settled.

REFERENCE NOTES

1. Mohanty, A.K. Perception of Ambiguous Sentences: Effects of Bias, Sentence Type, and Task. Paper presented at the annual convention of the Canadian Psychological Association, Toronto, June 1976.

2. Prideaux, G.D., Rowe, G.T., & Baker, W.J. Behavioral Variations in the Perception of Ambiguity. Paper presented at the annual meeting of the Rocky Mountain Linguistic Association, Edmonton, November 1975.

3. Prideaux, G.D. Surface Structure Resolution of Structural Ambiguity. Unpublished manuscript, 1975. [Available from Dr. G.D. Prideaux, Department of Linguistics, University of Alberta, Edmonton, Canada.]

4. Shangi, L.M. Autonomic Correlates of Levels of Processing in Memory. Unpublished doctoral dissertation, University of Alberta, 1976.

5. Bower, A.C. A manual of procedures for GSR and Heart Rate scoring. Unpublished manuscript, Centre for the study of Mental Retardation, University of Alberta, 1971.

6. Mohanty, A.K. Effects of bias and sentence type on perception of ambiguous sentences. Paper presented at the annual convention of Canadian Psychological Association, Vancouver, June 1977.

REFERENCES

Bever, T.G. The cognitive basis for linguistic structures. In J.R. Hays (Ed.), Cognition and the Development of Language. New York: John Wiley & Sons, 1970.

Bever, T.G. The integrated study of language behavior. In J. Morton (Ed.), Biological and Social Factors in Psycholinguistics. London: Logos Press, 1971.

Bever, T.G., Garrett, M.F., & Hurtig, R. The interaction of perceptual processes and ambiguous sentences. Memory and Cognition, 1973, 1, 277-286.

Bever, T.G., Lackner, J., & Kirk, R. The underlying structure of sentences are the primary units of immediate speech processing. Perception and Psychophysics, 1969, 5, 225-234.

Cairns, H.S. Ambiguous Sentence Processing. Doctoral Dissertation, The University of Texas, 1970.

Cairns, H.S., & Kamerman, J. Lexical Information Processing During Sentence Comprehension. Journal of Verbal Learning and Verbal Behavior, 1975, 14, 170-179.

Carey, P.W., Mehler, J., & Bever, T.G. Judging the veracity of ambiguous sentences. Journal of Verbal Learning and Verbal Behavior, 1970, 9, 243-254. (a)

Carey, P.W., Mehler, J., & Bever, T.G. When do we compute all the interpretations of an ambiguous sentence? In G.B. Flores d'Arcais and W.J.M. Levelt (Eds.), Advances in Psycholinguistics. Amsterdam: North-Holland Publishing, 1970. (b)

Carroll, J.B. Defining language comprehension. In J.B. Carroll & R.O. Freedle (Eds.), Language Comprehension and Acquisition of Knowledge. Washington, D.C.: V.H. Winston & Sons, 1972.

Chapin, P.G., Smith, T.S., & Abrahson, A.A. Two factors in perceptual Segmentation of speech. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 64-73.

Chomsky, N. Aspects of the theory of syntax. Cambridge, Mass: M.I.T. Press, 1965.

Clark, H.H. The language-as-fixed-effect fallacy: A critique of language statistics in psychological research. Journal of Verbal Learning and Verbal Behavior, 1973, 12, 335-359.

Clark, H.H., & Clark, E.V. Psychology and Language. New York: Harcourt Brace Jovanovich, 1977.

Coles, M.G. Physiological activity and detection: the effects of attentional requirements and the prediction of performance. Biological Psychology, 1974, 2, 113-125.

Coles, M.G., & Duncan-Johnson, C.C. Cardiac activity and information processing: the effects of stimulus significance and detection and response requirements. Journal of Experimental Psychology: Human Perception and Performance, 1975, 4, 418-428.

Conrad, C. Context effects in sentence comprehension: A study of subjective lexicon. Memory and Cognition, 1974, 2, 130-138.

Craik, F.I.M., & Lockhart, R.S. Levels of processing: A framework for memory research. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 671-684.

Dahl, H., & Spence, D.P. Mean heart rate predicted by task demand characteristics. Psychophysiology, 1971, 7, 369-376.

Das, J.P., & Bower, A.C. Autonomic responses of retarded adolescents during anticipation and feedback in probability learning. Journal of Mental Deficiency Research, 1973, 17, 171-175.

Elliott, R. The significance of heart rate for behavior: A critique of Lacey's hypothesis. Journal of Personality and Social Psychology, 1972, 22, 398-409.

Elliott, R. Further comment on the Lacey hypothesis. Journal of Personality and Social Psychology, 1974, 30, 19-23.

Empson, W. Seven Types of Ambiguity. London: Chalto and Windus, 1963. (Originally published, 1930.)

Fillenbaum, S. On coping with ordered and unordered conjunctive sentences. Journal of Experimental Psychology, 1971, 87, 93-98.

Fillenbaum, S. Pragmatic normalization: Further results for some conjunctive and disjunctive sentences. Journal of Experimental Psychology, 1974, 102, 574-578. (a)

Fillenbaum, S. Or: Some uses. Journal of Experimental Psychology, 1974, 103, 913-921. (b)

Fodor, J.A., Bever, T.G., & Garrett, M.F. The Psychology of Language, New York: McGraw-Hill, 1974.

Fodor, J.A., & Garrett, M. Some syntactic determinants of sentential complexity, Perception and Psychophysics, 1967, 2, 289-296.

Fodor, J.A., Garrett, M.F., & Bever, T.G. Some syntactic determinants of sentential complexity, II: Verb structure. Perception and Psychophysics, 1968, 3, 456-461.

Foss, D. Some effects of ambiguity upon sentence comprehension. Journal of Verbal Learning and Verbal Behavior, 1970, 9, 699-706.

Foss, D., Bever, T.G., & Silver, M. The comprehension and verification of ambiguous sentences. Perception and Psychophysics, 1968, 4, 304-306.

Foss, D., & Jenkins, C.M. Some effects of context on the comprehension of ambiguous sentences. Journal of Verbal Learning and Verbal Behavior, 1973, 12, 577-589.

Garcia, E. Some remarks on "Ambiguity" and "Perceptual Processes". Journal of Psycholinguistic Research, 1976, 5, 195-213.

Garrett, M.F. Does ambiguity complicate the perception of sentences? In G.B. Flores d'Arcais and W. Levelt (Eds.), Advances in Psycholinguistics. Amsterdam. North-Holland Publishing, 1970.

Graham, F.K., & Jackson, J.C. Arousal Systems and Infant Heart Rate Responses. In H.W. Reese & L.P. Lipsitt (Eds.), Advances in Child Development and Behavior (Vol. 5). New York: Academic Press, 1970.

Gunn, C.G., Wolf, S., Block, T.R. & Penson, R.J. Psychophysiology of the cardiovascular system. In N.S. Greenfield & R.A. Sternbach (Eds.), Handbook of Psychophysiology, New York: Holt, 1972.

Hahn, W.W. Attention and heart rate: A critical appraisal of the hypothesis of Lacey and Lacey. Psychological Bulletin, 1973, 79, 59-70.

Hakes, D.T., & Cairns, H.S. Sentence comprehension and relative pronouns. Perception and Psychophysics, 1970, 8, 5-8.

Jennings, R.I. Cardiac reaction and different developmental levels of cognitive functioning. Psychophysiology, 1971, 8, 433-450.

Johnson-Laird, P.N. Experimental Psycholinguistics. Annual Review of Psychology, 1974, 25, 135-160.

Kahneman, D., Tursky, B., Shapiro, D., & Crider, A. Pupilary, Heart Rate, and Skin Resistance changes during a mental task. Journal of Experimental Psychology, 1969, 79, 164-167.

Katz, J.J. Semantic Theory. New York: Harper & Row, 1972.

Katz, J.J., & Postal, P.M. An integrated theory of linguistic descriptions. Cambridge, Mass.: M.I.T. Press, 1964.

Kooij, J.G. Ambiguity in Natural Language. Amsterdam: North-Holland, 1971.

Lacey, J.I. Psychophysiological approaches to the evaluation of psychotherapeutic process and outcome. In E. Rubenstein and M. Parloff (Eds.), Research in Psychopherapy (Vol. 1). Washington: American Psychological Association, 1959.

Lacey, J.I. Somatic response patterning and stress: some revisions of activation theory. In M.H. Appley and R. Prumbull (Eds.), Psychological Stress: Issues in Research. New York: Appleton-Century-Crofts, 1967.

Lacey, J.I. Some cardiovascular correlates of sensory motor behavior: Examples of viscatral abberent feedback? In C.H. Hockman (Ed.), Limbic System Mechanism and Autonomic Function. Springfield: Charles Thomas, 1972.

Lacey, J.I., Kagan, J., Lacey, B., & Moss, H.A. The visceral end: Situational determinants and behavioral correlates of autonomic response pattern. In P.K. Knapp (Ed.), Expression of the emotions in man. New York: International, 1963.

Lacey, J.I., & Lacey, B.C. Some autonomic-central nervous system interrelationship. In P. Black (Ed.), Physiological correlates of emotion. New York: Academic press, 1970.

Lackner, J., & Garrett, M. Resolving Ambiguity: Effects of biasing context in the unattended ear. Cognition, 1972, 1, 359-372.

Lashley, K.S. The problem of serial order in behavior. In L.A. Jeffress (Ed.), Cerebral Mechanisms in Behavior, New York: Wiley, 1951.

Lenneberg, E.H. The Concept of Language Differentiation. In E.H. Lenneberg and E. Lenneberg (Eds.), Foundations of Language Development (Vol. 1). New York: Academic Press, 1975.

Lewis, M., & Wilson, C.D. The Cardiac Response to a perceptual cognitive task in the young child. Psychophysiology, 1970, 6, 411-420.

Libby, W.L., Lacey, B.C., & Lacey, J.I. Pupilary and Cardiac Activity during Visual Attention. Psychophysiology, 1972, 10, 270-294.

MacKay, D.G. To end ambiguous sentences. Perception and Psychophysics, 1966, 1, 426-436.

MacKay, D.G. Mental Diplopia: A model of speech perception. In G.B. Flores d'Arcais and W.J.M. Levelt (Eds.), Advances in Psycholinguistics. Amsterdam: North-Holland, 1970.

MacKay, D.G., & Bever, T.G. In search of ambiguity. Perception and Psychophysics, 1967, 2, 193-200.

McCanne, T.R., & Sandman, C.A. Instrumental Heart Rate Responses and Visual Perception: A preliminary study. Psychophysiology, 1974, 11, 283-287.

McGuigan, F.J. Electrical Measurement of Covert Processes as an Explication of "Higher Mental Events". In F.J. McGuigan and R.A. Schoonover (Eds.), The Psychophysiology of Thinking. New York: Academic Press, 1973.

Miller, G.A., Galanter, E., & Pribam, K.H. Plans and the Structure of Behavior. New York: Holt, Rinehart, & Winston, 1960.

Miller, G.A., & Johnson-Laird, P.N. Language and Perception. Cambridge, Mass.: Harvard University Press, 1976.

Mistler-Lachman, J.L. Levels of comprehension in processing of normal and ambiguous sentences. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 614-623.

Mistler-Lachman, J.L. Queer sentences, Ambiguity, and levels of processing. Memory and Cognition, 1975, 3, 395-400.

Obrist, P.A. Cardiovascular differentiation of sensory stimuli. Psychosomatic Medicine, 1963, 25, 450-459.

Obrist, P.A., & Webb, R.A. Heart Rate during conditioning on dogs: Relationship to somatic motor activity. Psychophysiology, 1967, 4, 7-34.

Obrist, P.A., Webb, R.A., & Sutterer, J.R. Heart Rate and Somatic Changes during aversive conditioning and simple reaction time tasks. Psychophysiology, 1969, 5, 696-723.

Obrist, P.A., Webb, R.A., Sutterer, J.R., & Howard, J.L. Cardiac deceleration and reaction time: An evaluation of two hypotheses. Psychophysiology, 1970, 6, 695-706.

Olson, D.R. Language and Thought: Aspects of a Cognitive Theory of Semantics. Psychological Review, 1970, 77, 257-273.

Olson, G.M., & Clark, H.H. Research methods in Psycholinguistics. In E.C. Carterette and M.P. Friedman (Eds.), Handbook of Perception (Vol. 7): Language and Speech. New York: Academic Press, 1976.

Olson, J.M., & MacKay, D.G. Completion and Verificaiton of Ambiguous Sentences. Journal of Verbal Learning and Verbal Behavior, 1974, 13, 457-470.

Osgood, C.E., May, W.H., & Miron, M.S. Cross-cultural Universals of Affective Meaning. Urbana: University of Illinois Press, 1975.

Osgood, C.E., & McGuigan, F.J. Psychophysiological Correlates of Meaning: Essences or Tracers? In F.J. McGuigan and R.A. Schoonover (Eds.), The Psychophysiology of Thinking. New York: Academic Press, 1973.

Osgood, C.E., Suci, G.J., & Tannenbaum, P. The measurement of meaning. Urbana: University of Illinois Press, 1957.

Paivio, A. Psychophysiological Correlates of Imagery. In F.T. McGuigan and R.A. Schoonover (Eds.), The Psychophysiology of Thinking. New York: Academic Press, 1973.

Reber, A.S., & Anderson, J.R. The perception of clicks in linguistic and nonlinguistic messages. Perception and Psychophysics, 1970, 8, 81-89.

Rubenstein, H., Garfield, L: & Millikan, J.A. Homographic Entries in the Internal Lexican. Journal of Verbal Learning and Verbal Behavior, 1970, 9, 487-494.

Schvaneveldt, R.W., Meyer, D.E., & Becker, C.A. Lexical Ambiguity, Semantic Context, and Visual Word Recognition. Journal of Experimental Psychology: Human Perception and Performance, 1976, 2, 243-256.

Shannon, B. The two meanings of a homophone. Perception and Psychophysics, 1974, 16, 571-574.

Seigel, S. Nonparametric Statistics for the Behavioral Sciences. New York: McGraw-Hill, 1956.

Sokolov, E.N. Neuronal models and orienting reflex. In M.A.B. Brazier (Ed.), The Central Nervous System and Behavior. New York: Josiah Macy Foundation, 1960.

Sokolov, E.N. Perception and Conditioned Reflex, New York: McMillan, 1963.

Stennett, R.G. Alpha amplitude and arousal. Psychophysiology, 1966, 2, 372-376.

Thorne, J.P. On hearing sentences. In J. Lyons and R.J. Wales (Eds.), Psycholingiustic Papers, Edinburgh: Edinburgh University Press, 1966.

Tursky, B., Schwartz, G.E., & Crider, A. Differential Patterns of Heart Rate and Skin resistance during a digit transformation task. Journal of Experimental Psychology, 1970, 83, 451.

Webb, R.A., & Obrist, P.A. The psysiological concomitants of reaction time perfcrmance as a function of preparatory interval series. Psychophysiology, 1970, 6, 389-403.

Winer, B.J. Statistical Principles in Experimental Design. New York: McGraw-Hill, 1971.

Wingfield, A., & Klein, J. Syntactic structure and acoustic pattern in speech perception. Perception and Psychophysics, 1970, 9, 23-28.

APPENDIX: A

Sentence Interpretation and Ambiguity Rating Questionnaire
(with the lists of sentences)

PART I

This is a study to investigate how English speaking adults analyse and understand sentences. Given here is a list of sentences which can occur in any conversation. We are interested in your reaction to these sentences when presented in isolation as this might shed light on the way sentences are normally analysed. Please read each sentence carefully and write another sentence to paraphrase the one given. Your paraphrase should interpret the sentence clearly. If some sentences seem ambiguous to you, give the interpretation that comes to you first. Work at a fairly high speed. It is your first impression, the immediate 'feeling' about the sentences that we want. On the other hand, please do not be careless because we want your true impression. Please make sure to paraphrase all the sentences.

(Write your paraphrases starting from the next page)

LIST OF SENTENCES

(Please write your paraphrases in the space below each sentence)

1. THE ANSWER SEEMED CLEAR IN THE CHEMISTRY CLASS.

---

2. THE DELIVERY BOY REFUSED TO CARRY OUT THE ORDER.

---

3. THE REALTOR WANTED LOTS OF THE SAME SIZE.

---

4. THE COOK KNEW HOW GOOD BEEF TASTED.

---

5. THE GRADUATING DOCTORS WERE THE ONES TO WATCH.

---

6. THE PHARMACIST COULD NOT FIND ANY NEW SOLUTION.

---

7. THE CLIMATE OFTEN BOTHERS THE DOCTOR'S PATIENT.

---

8. THE LAWER INSISTED THAT THE CHARGE WAS UNJUST.

---

9. JOHN KNEW THAT FLYING PLANES COULD BE DANGEROUS.

---

10. JIM'S FRIENDS HAVE MISPLACED ALL THE RECORDS.

---

11. THE ROAR OF THE SPECTACTORS DISTURBED THE CHESS PLAYERS.

---

12. THE POLICE WANTED TO OPEN THE CASE.

---

13. THE CLIENTS DISCUSSED WITH THE LAWER THEIR PROBLEMS.

---

14. THE WAITRESS SERVED THE MAN WITH A SMILE.

---

15. THE CUSTOMER INSISTED THAT THE BILL WAS UNJUST.

---

16. JACK PUT ON ANOTHER COAT BEFORE THE EVENING.

---

17. MARCIA BOUGHT THE NEW GLASSES LAST WEEK.

---

18. SYLVIA DROPPED A SPOON ON THE TABLE.

LIST OF SENTENCES

(Please write your paraphrases in the space below each sentence)

1. THE DELIVERY BOY REFUSED TO TAKE OUT THE ORDER.

---

2. I DON'T LIKE SAILING IN THE HARBOUR.

---

3. THE PHARMACIST COULD NOT FIND ANY NEW LIQUID.

---

4. SOME SOLDIERS LOST THEIR ARMS IN THE BATTLE.

---

5. THE MASTER KNEW HOW GREAT SYMPHONIES AMUSE.

---

6. THE GENERAL SENT THE TROOPS OVER A MONTH AGO.

---

7. RUTH THINKS THAT THE CHARGE IS UNJUST.

---

8. THE GRADUATING DOCTORS WERE THE ONES TO STAND.

---

9. THE COLD OFTEN BOTHERS THE DOCTOR'S PATIENT.

---

10. THE NEW BALLET DANCERS ARE AMUSING PEOPLE.

---

11. THE LAWYER INSISTED THAT THE ACCUSATION WAS UNJUST.

---

12. THE STORY OF THE SALESMAN WAS VERY FUNNY.

---

13. THE OLD MAN DOES NOT LIKE SMOKING.

---

14. JIM'S FRIENDS HAVE MISPLACED ALL THE DOCUMENTS.

---

15. THE ROAR OF THE FANS DISTURBED THE CHESS PLAYERS.

---

16. THE CUSTOMER INSISTED THAT THE CHARGE WAS UNJUST.

---

17. THE OLD MAN WAS LYING WHEN THE DOCTOR CAME.

---

18. SYLVIA DROPPED A SPADE ON THE TABLE.

LIST OF SENTENCES

(Please write your paraphrases in the space below each sentence)

1. THE SALESMAN WANTED LOTS OF THE SAME SIZE.

---

2. TOM ASKED ME TO GO WITHOUT HESITATION.

---

3. THE DRIVER TOOK A LEFT TURN AT THE INTERSECTION.

---

4. THE CHAIRMAN OF THE DEPARTMENT HAS TWO APPOINTMENTS.

---

5. THE RIVER BANK WAS FLOODED DUE TO THE RAIN.

---

6. JOHN IS THE ONE TO HELP TODAY.

---

7. THE GROWTH OF THE SPRING FLOWERS WAS MARVELLOUS.

---

8. THERE ARE SPECIAL BUSES FOR OLD MEN AND LADIES.

---

9. BILL CLAIMED THAT DON WAS QUICK TO PLEASE.

---

10. THE GIRL BROKE THE MIRROR IN THE BATHROOM.

---

11. THE SOLUTION SEEMED CLEAR IN THE CHEMISTRY CLASS.

---

12. THE PEOPLE WERE SURPRISED AT THE MAYOR'S SELECTION.

---

13. MAKE SURE THAT JIM TAKES A RIGHT TURN.

---

14. THE BUSINESSMAN BECAME RICH BECAUSE OF HIS INDUSTRY.

---

15. VISITING THE RELATIVES COULD BE BOTHERSOME FOR THE COUPLE.

---

16. EICHMAN WAS TALKING WHEN THE LAWYER ENTERED.

---

17. THE PRESIDENT GAVE A LECTURE ABOUT REMEMBERANCE DAY.

---

18. ONLY THE YOUNG PEOPLE LAUGH AT THE CHURCH.

LIST OF SENTENCES

(Please write your paraphrases in the space below each sentence)

1. MARCL BOUGHT THE NEW EYE-GLASSES LAST WEEK.

---

2. THE CLIENTS DISCUSSED THEIR PROBLEMS WITH THE LAWYER.

---

3. JACK PUT ON ANOTHER PAINT BEFORE THE EVENING.

---

4. FRED IS THE YOUNGEST PERSON IN THE PARTY.

---

5. THE IDEA OF THE NATIVES WAS DREADFUL.

---

6. THE BANK WAS FLOODED DUE TO HEAVY RAIN.

---

7. BILL CLAIMED THAT DON WAS EASY TO PLEASE.

---

8. THE DRIVER TOOK A RIGHT TURN AT THE INTERSECTION.

---

9. THE GROWING OF THE SPRING FLOWERS WAS MARVELLOUS.

---

10. THERE ARE SPECIAL BUSES FOR LADIES AND OLD MEN.

---

11. THE WORKER WAS CONTINUALLY BOTHERED BY THE COLD.

---

12. EICHMAN WAS LYING WHEN THE LAWYER ENTERED.

---

13. ONLY THE YOUNG PEOPLE LAUGH IN THE CHURCH.

---

14. VISITING RELATIVES COULD BE BOTHERSOME FOR THE COUPLE.

---

15. THE MAYOR REQUESTED THE POLICE TO STOP DRINKING.

---

16. THE PRESIDENT GAVE A LECTURE ON REMEMBERANCE DAY.

---

17. THE PEOPLE WERE SURPRISED AT THE MAYOR'S DECISION.

---

18. THE MASTER KNEW HOW GREAT SYMPHONIES SOUND.

PART II

Please refer to the list of sentences once more. For each sentence, note in the form given;

i) whether the sentence seemed ambiguous to you on your first reading,

ii) whether it seems ambiguous to you now, and if the answer to either i or ii is 'yes',

iii) write a paraphrase to show the meaning of the sentence other than the one you have paraphrased earlier,

Further,

iv) rate each sentence on a 7-point scale of Ambiguity like the one given below:

Non-ambiguous : 1 : 2 : 3 : 4 : 5 : 6 : 7 : Ambiguous

If you think that the sentence is not ambiguous at all, you should rate the sentence as 1; if you think it is highly ambiguous rate it as 7. If it seems fairly ambiguous to you rate it as 4 and so on. Remember: The more ambiguous a sentence is the higher is its rating in a 7-point scale. Again, work fairly quickly.

Thank you very much for your cooperation.

For each sentence please answer the following:

Sentence Number	i Did it seem ambiguous to you on first reading? (Circle one)	ii Does it seem ambiguous to you now? (Circle one)	iii If the answer to either i or ii is 'yes', write a paraphrase to show the meaning of the sentence other than the one you have paraphrased earlier.	iv Rating on 7-point scale of Ambiguity
1.	yes/no	yes/no		
2.	yes/no	yes/no		
3.	yes/no	yes/no		
4.	yes/no	yes/no		
5.	yes/no	yes/no		
6.	yes/no	yes/no		
7.	yes/no	yes/no		
8.	yes/no	yes/no		
9.	yes/no	yes/no		
10.	yes/no	yes/no		
11.	yes/no	yes/no		
12..	yes/no	yes/no		
13.	yes/no	yes/no		
14.	yes/no	yes/no		
15.	yes/no	yes/no		

Sentence Number	i Did it seem ambiguous to you on first reading? (Circle one)	ii Does it seem ambiguous to you now? (Circle one)	iii If the answer to either i or ii is 'yes', write a paraphrase to show the meaning of the sentence other than the one you have paraphrased earlier.	iv Rating on 7-point scale of Ambiguity
16.	yes/no	yes/no		
17.	yes/no	yes/no		
18.	yes/no	yes/no		

APPENDIX: B

Stimulus Sentences and Probe Words used in the study

EXPERIMENT 1

Sentences[1]	Probe Words & Type
(List 1)	
The worker was continually bothered by the cold.*	WINTER (Y:d)
The office was flooded due to the heavy rain.	DANCING (N:un)
The chemical liquid seemed clear in the chemistry class.	COLOR (Y:un)
The businessman became rich because of his industry.**	SKY (N:am)
The realtor wanted plots of the same size.	DAY (N:un)
Sylvia dropped a playing card on the table.	GAME (Y:un)
Jim's friends have misplaced all the records.*	TREE (N:am)
The driver took a correct turn at the intersection.	HELP (N:un)
The roar of the fans disturbed the chess players.**	CONCENTRATION (Y:b)
The lawyer insisted that the price was unjust.	COSTLY (Y:un)
Jack put on another jacket before evening.	HARBOUR (N:un)
The chairman of the department has two jobs.	ADMINISTRATION (Y:un)
(List 2)	
The driver took a right turn at the intersection.*	TRAFFIC (Y:b)
The answer seemed clear in the chemistry class.	HEALTH (N:un)
The land was flooded due to the heavy rain.	WATER (Y:un)
The realtor wanted lots of the same size.*	DAY (N:am)
Jim's friends have misplaced all the record albums.	MUSIC (Y:un)
The roar of the ventilators disturbed the chess players.	GREEN (N:un)
The lawyer insisted that the accusation was unjust.	PICTURE (N:un)
The chairman of the department has two appointments.**	MOUNTAIN (N:am)

Jack put on another coat of paint before evening.	BRUSH (Y:un)
Sylvia dropped a spade on the table.**	GAME (Y:d)
The businessman became rich because of his factory.	SKY (N:un)
The worker was continually bothered by the weather.	WINTER (Y:un)

(List 3)

The realtor wanted many items of the same size.	BUSINESS (Y:un)
The bank was flooded due to the heavy rain.**	DANCING (N:am)
Sylvia dropped a spoon on the table.	BOY (N:un)
The solution seemed clear in the chemistry class.**	COLOR (Y:n-d)
The driver took a left turn at the intersection.	TRAFFIC (Y:un)
The chairman of the department has two engagements.	MOUNTAIN (N:un)
Jack put on another coat before evening.*	HARBOUR (N:am)
The businessman became rich because of hard work.	MONEY (Y:un)
The worker was continually bothered by the disease.	TELEPHONE (N:un)
The lawyer insisted that the charge was unjust.*	COSTLY (Y:n-d)
The roar of the spectators disturbed the chess players.	CONCENTRATION (Y:un)
Jim's friends has misplaced all the books.	TREE (N:un)

Note 1: Sentences are listed in the order of presentation.

* High bias ambiguous sentences.
** Low bias ambiguous sentences.

EXPERIMENT 2

Sentences[1]	Probe Words & Type
(List 1	
General sent the troop more than a month ago.	COLOR (N:un)
The cook knew how beef tasted good.	MEAT (Y:un)
Visiting relatives could be bothersome for the couple.***	GAME (N:am)
On remembrance day the president gave a lecture.	MEETING (Y:un)
The pharmacist could not find any correct answer.	BOY (N:un)
Marcia bought the wine glasses last week.	DRINKING (Y:un)
Only the young people laugh at the church.**	RELIGION (Y:am)
John is the one to help us today.	VOLUNTEER (Y:un)
Fred is the youngest person in the party.*	SKY (N:am)
The disease often bothers the doctors patient.	HARBOUR (N:un)
Bill claimed that Don was easy to please.	SATISFY (Y:un)
The salesman wanted lots of the same size.*	BUSINESS (Y:am)
The new ballet dancers are funny people.	DAY (N:un)
The old man does not like smoking.***	CIGARETTE (Y:am)
The graduating doctors were the ones to get attention.	ICE (N:un)
The police wanted to open the investigation.	STEALING (Y:un)
Tom asked me to go without hesitation.**	CLOUD (N:am)
The mayor requested the police to forbid drinking.	BRUSH (N:un)
(List 2	
The police wanted to open the brief case.	MOUNTAIN (N:un)
Fred is the youngest person in the meeting.	GATHERING (Y:un)
The pharmacist could not find any chemical mixture.	LIQUID (Y:un)

The new ballet dancers are amusing people.**	DAY (N:am)
Only the young people dishonor the church.	RELIGION (Y:un)
The cold often bothers the doctor's patient.*	WINTER (Y:am)
The general sent over the troops a month ago.	BATTLE (Y:un)
Bill claimed that Don was quick to please.***	TRAFFIC (N:am)
The visiting relatives could be bothersome for the couple.	GUEST (Y:un)
The old man does not allow smoking.	PICTURE (N:un)
The graduating doctors were the ones to stand.	MEDICINE (Y:un)
Marcia bough the new glasses last week.*	TREE (N:am)
The president gave a lecture about rememberance day.	WATER (N:un)
John is the one to need help today.	GREEN (N:un)
The cook knew how good beef tasted.**	MEAT (Y:am)
The salesman wanted many items of the same size.	DANCING (N:un)
The mayor requested the police to stop drinking.***	BEER (Y:am)
Without hesitation Tom asked me to go.	CLOUD (N:un)

(List 3

The salesman wanted plots of the same size.	BUSINESS (Y:un)
The president gave a lecture on rememberance day.**	MEETING (Y:am)
Fred is the youngest person in the organization.	SKY (N:un)
The graduating doctors were the ones to watch.***	MEDICINE (Y:am)
The weather often bothers the doctor's patient.	WINTER (Y:un)
The mayor requested the police to quit drinking.	BEER (Y:un)
The police wanted to open the case.*	MOUNTAIN (N:am)
The old man does not like to smoke.	CIGARETTE (Y:un)
The cook knew how fresh beef tasted.	MUSIC (N:un)
Bill claimed that Don was eager to please.	TRAFFIC (N:un)
Maria bought the new eyeglasses last week.	TREE (N:un)
Tom asked me to go without him.	REQUEST (Y:un)
The general sent the troops over a month ago.**	COLOR (N:am)
The new ballet dancers are amusing the people.	PLEASANT (Y:un)

Visiting the relatives could be bothersome for the couple.	GAME (N:un)
The pharmacist could not find any solution.*	LIQUID (Y:am)
Only the young people laugh in the church.	TELEPHONE (N:un)
John is the one to help today.***	GREEN (N:am)

Note 1: Sentences are listed in the order of presentation.

* Ambiguous sentences -- Lexical.
** Ambiguous sentences -- Surface structural.
*** Ambiguous sentences -- Deep structural.

APPENDIX: C

A comparative summary of the
models
of Ambiguous Sentence Perception

Models of Ambiguous Sentence Perception
A comparative summary

Unitary Perception Model	Perceptual Closure Model	Perceptual Suppression Model
1. Unitary perception by selective access to one meaning of ambiguous sentences.	1. Exhaustive computation; both meanings are non-selectively accessed.	1. Exhaustive computation; both meanings are non-selectively accessed.
2. Processing of ambiguous sentences is not more complex than unambiguous ones.	2. Processing of ambiguous sentences is more complex than unambiguous ones.	2. Processing of ambiguous sentences is more complex than unambiguous ones.
3. When two meanings are perceived, perception of one is independent of perception of the other.	3. Both meanings are processed until a perceptual closure at the clause boundary. Beyond this point only one meaning is retained.	3. Both meanings interact in a mutually suppressive manner until one is activated and the other meaning is released from inhibition. In effect, there is a perceptual fluctuation from one meaning to the other.
4. a) Prior context, bias, and set etc. help priming one meaning that is perceived. b) Subsequent context justifying the second (not perceived) meaning initiates reprocessing of the ambiguous sentences.	4. Context, bias, and set factors probably help selection of one of the two meanings but do not affect perceptual complexity due to access of two meanings.	4. As the probability of one of the two meanings increases due to the effects of bias, context, and set etc., the processing difficulty decreases.

5. Tasks given during the processing of sentences do not differentiate ambiguous and unambiguous sentences.	5. a) Pre-closure tasks differentiate ambiguous and unambiguous sentences; post-closure task do not do so. b) Tasks requiring a response for which any one meaning is acceptable show facilitative effect of ambiguity, whereas tasks requiring a choice among the meanings show performance difficulty due to sentence ambiguity.	5. Tasks given during the processing of sentences show greater difficulty due to ambiguity.
6. For different types of ambiguous sentences processing is not more complex than similar unambiguous sentences.	6. a) In the case of tasks for which perception of any one meaning is suitable (e.g. sentence production task), facilitation due to ambiguity is greatest for the deep structure type, followed by surface structure and lexical types. b) In case of tasks requiring a choice among the two meanings (e.g. sentence completion task) performance difficulty due to ambiguity is greatest for deep structure type, followed by surface structure and lexical types.	6. No specific relationship between perceptual complexity and type of ambiguous sentences.